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Diesel Particulate Matter Exposure of Underground Coal Miners; Final Rule

30 CFR Part 57

Diesel Particulate Matter Exposure of Undergound Metal and Nonmetal Miners; Final Rule

DEPARTMENT OF LABOR

Mine Safety and Health Administration

30 CFR Part 72

RIN 1219–AA74

Diesel Particulate Matter Exposure of Underground Coal Miners

AGENCY: Mine Safety and Health Administration (MSHA), Labor.

ACTION: Final rule.

SUMMARY: This rule establishes new health standards for underground coal mines that use equipment powered by diesel engines.

This rule is designed to reduce the risks to underground coal miners of serious health hazards that are associated with exposure to high concentrations of diesel particulate matter (dpm). DPM is a very small particle in diesel exhaust. Underground miners are exposed to far higher concentrations of this fine particulate than any other group of workers. The best available evidence indicates that such high exposures put these miners at excess risk of a variety of adverse health effects, including lung cancer.

The final rule for underground coal mines would require that the dpm emissions from certain pieces of equipment be restricted to prescribed levels. Underground coal mine operators would also be required to train miners about the hazards of dpm exposure.

By separate notice, MSHA will publish a rule to reduce dpm exposures in underground coal mines.

DATES: The provisions of the final rule are effective March 20, 2001. However, § 72.500(b) will not apply until July 19, 2002; §72.501(b) will not apply until July 21, 2003; and, §72.501(c) will not apply until January 19, 2005.

FOR FURTHER INFORMATION CONTACT: David L. Meyer, Director, Office of Standards, Regulations, and Variances, MSHA, 4015 Wilson Boulevard, Arlington, VA 22203–1984. Mr. Meyer can be reached at dmeyer@msha.gov (Internet E-mail), 703–235–1910 (voice), or 703–235–5551 (fax). You may obtain copies of the final rule in alternative formats by calling this number. The alternative formats available are either a large print version of the final rule or the final rule in an electronic file on computer disk. The final rule also is available on the Internet at http://www.msha.gov/REGSINFO.HTM.

SUPPLEMENTARY INFORMATION:

I. Key Features of MSHA's Final Rule Limiting the Concentration of Diesel Particulate Matter (DPM) in Underground Coal Mines

(1) What are the requirements for permissible equipment?

Permissible equipment must not emit more than 2.5 grams per hour of dpm, as measured in a laboratory test. Any permissible equipment that is added to a mine's inventory underground more than 60 days after the date this rule is published will have to meet this standard upon introduction. This includes newly purchased equipment, used equipment, or a piece of equipment receiving a replacement engine with a different serial number than the engine it is replacing, including engines or equipment coming from one mine into another. It does not include a piece of equipment whose engine was previously part of the mine's inventory and rebuilt.

Within 18 months from the date the rule is issued, the entire permissible fleet must meet this standard.

The rule leaves the choice of controls used to achieve the emissions limit to operators. Operators may use any combination of controls (*e.g.,* cleaner engine, OCC, filter) to meet the emissions standard specified in this section.

As a practical matter, MSHA expects that to comply with this standard, most permissible equipment will be equipped with a paper filter. As explained in Part IV of this preamble, MSHA has verified that there are commercially available paper filters which will allow 99% of the existing 541 units in the permissible fleet to meet this requirement—including permissible units powered by the Deutz MWM 916, the Caterpillar 3304 and the Caterpillar 3306. Commercially available paper filters capable of bringing the emissions of these units into compliance include a model which can be installed directly on the exhaust coming from a water scrubber or on the exhaust coming from a heat exchanger, as well as the integrated DST® system. Other filters which use paper with the same performance characteristics will also be acceptable. Control devices whose dpm removal efficiency has not been demonstrated by laboratory testing on a diesel engine can be evaluated following the procedures in 30 CFR 72.503 of this part added by this rulemaking. Moreover, the rule provides that MSHA may rely upon the test results of other organizations who perform equivalent tests.

MSHA will publish on its web site a list of tested control devices and their performance. Compliance will be determined by reference to this data—there will be no in-mine testing.

The only engine which might not be able to meet these requirements for dpm emissions from permissible equipment with a paper filter is the Isuzu QD–100. MSHA's inventory indicates there are currently only two units of permissible equipment using this engine; however, these two units can comply at a derated power setting.

The engines currently approved for permissible use are generally high in particulate emissions. MSHA is committed to taking actions which will facilitate the approval for permissible use of the lower-emission engines which have become available in recent years. These actions could include waiving test fees, contracting for the performance of such tests, or on an interim basis permitting the use of an engine approved for nonpermissible use in a permissible package. MSHA will solicit input from the mining community, through a **Federal Register** notice as it considers how to proceed in this regard.

(2) What are the requirements for heavy-duty non-permissible equipment?

Non-permissible heavy duty equipment will ultimately not be permitted under the final rule to emit more than 2.5 grams per hour of dpm. For reasons of feasibility, this requirement will be implemented in phases.

Any heavy duty equipment added to a mine's inventory more than 60 days after the date of publication of this rule will have to comply with an interim emissions limit for that machine of 5.0 gr/hr. This includes newly purchased equipment, used equipment, or a piece of equipment receiving a replacement engine with a different serial number than the engine it is replacing, including engines or equipment coming from one mine into another. It does not include a piece of equipment whose engine was previously part of the mine's inventory and rebuilt.

All heavy duty equipment in the fleet must meet the interim standard of 5.0 grams per hour of dpm in 30 months.

Finally, another 18 months later (4 years in all), all nonpermissible heavy duty equipment in the fleet will have to meet the final standard of 2.5 grams per hour of dpm.

As with permissible equipment, the rule leaves the choice of controls used to achieve the emissions limit to operators. Any combination of controls (*e.g.,* cleaner engine, OCC, filter) can be used as long as compliance with the standard specified in this section is met.

As a practical matter, MSHA believes that most existing heavy duty equipment will utilize commercially available hot gas filters (*e.g.,* ceramic cell, wound fiber, sintered metal, etc.) to comply with the final limit. All the existing fleet can reach the interim limit with such a filter; some will not need one. MSHA determined that all but a few can reach the final limit with such a filter.

The rule provides that MSHA may rely upon the test results of organizations who perform filtration efficiency tests. In this regard, MSHA will accept the results of filter tests performed by VERT. VERT is an acronym for Verminderung der Emissionen von Realmaschinen in Tunnelbau, a consortium of several European agencies conducting diesel emission research in connection with major planned tunneling projects in Austria, Switzerland and Germany. VERT was established to advance hot gas filter technology due to concerns in Europe about dpm levels. This gave VERT the opportunity to acquire the necessary filter evaluation expertise. A wide range of commercially available hot gas filters have been tested by VERT and the filtration efficiency determined. The Secretary may also accept filter efficiency test results from other testing organizations that can demonstrate a high level of expertise in filter evaluation (see § 72.503(c) of the final rule).

Operators using the DST'' system with the catalytic convertor on heavy duty equipment, or the Jeffrey dry exhaust system, will also be deemed in compliance with the final rule, since test results conducted in the same manner as the requirement in the final rule demonstrate that those systems can reduce the emissions from all existing heavy duty engines to below the limit. Filtration devices whose filter efficiency has not been demonstrated by testing on a diesel engine can be evaluated following the procedures in 30 CFR 72.503 of this part added by this rulemaking.

MSHA will publish on its web site a list of tested control devices and their performance. Compliance will be determined by reference to this data—there will be no in-mine testing.

The standard may also be met through the use of newer, cleaner engines in some heavy duty equipment with low horsepower engines. There are already many engines approved for non-permissible use in underground coal mines that will enable heavy duty equipment to limit emissions, thus allowing the use of lower efficiency filters. MSHA is also considering approaches that would expedite the approval of additional engines based on evidence that such engines meet EPA standards which ensure the engines are at least as clean as required under MSHA approval standards.

(3) What are the requirements for generators and compressors?

The final rule provides that generators and compressors meet the same dpm emissions standards as heavy duty equipment. Thus, generators and compressors will ultimately not be permitted to emit more than 2.5 grams per hour of dpm. Generators and compressors introduced into the fleet of an underground coal mine more than 60 days after the final rule is published will have to meet an interim emissions limit of 5.0 g/hr. Generators and compressors in the existing fleet will have 30 months to meet the interim standard of 5.0 grams per hour of dpm. After an additional 18 months (4 years in all), all generators and compressors underground will have to meet the final standard of 2.5 grams per hour of dpm.

Although the proposed rule would not have covered generators and compressors, MSHA explicitly asked the mining community if there were types of light duty equipment that should, because of operating characteristics, be treated like heavy duty equipment. Generators and compressors generate more dpm emissions than other light-duty equipment based on their known duty cycle and type of work for which they are designed; indeed, they use engines whose horsepower often exceeds that in permissible equipment. Accordingly, MSHA has determined they should be covered by this rulemaking.

MSHA's inventory indicates that the 34 generators and 29 compressors constitute less than 3% of the underground light duty diesel fleet. The existing compressors are using engines which should meet the standard's interim and final requirements with a commercially available hot gas filter.

Generators and compressors will be able to utilize the same technologies as heavy duty machines to comply with this standard. This will include hot gas filters or paper filters, as appropriate. Smaller generators and compressors may utilize the clean engine technologies.

(4) What are the requirements for other nonpermissible equipment?

The final rule provides that any piece of nonpermissible light-duty equipment introduced into an underground coal mine more than 60 days after the date of publication of the rule must not emit more than 5.0 grams per hour of dpm. This includes newly purchased equipment, used equipment, or a piece of equipment receiving a replacement engine with a different serial number than the engine it is replacing, including engines or equipment coming from one mine into another, but it does not include a piece of equipment whose engine was previously part of the mine's inventory and rebuilt.

The final rule does not impose any new requirements on the existing nonpermissible light-duty fleet (except for generators and compressors as noted above).

While new light duty equipment would not have been covered by the proposed rule, MSHA explicitly asked the mining community if it would be feasible to cover such new light duty equipment, even if it were not feasible to set limits for all light duty equipment. MSHA has determined that it is feasible to require that newly introduced light duty equipment meet the same 5 gr/hr standard as new heavy duty equipment.

To facilitate compliance with this standard, light duty equipment which uses an engine meeting certain EPA standards listed in the MSHA rule will be deemed to automatically meet the MSHA dpm standard for newly introduced light-duty equipment. For example, any ''heavy duty highway engine'' produced after 1994 will be deemed to meet this dpm standard. The agency has determined that there are already MSHA approved engines available in a full range of horsepower sizes that can meet the EPA standards listed in this final rule.

In practice, what this rule does is simply ensure that very old engines with few, if any, emission controls are not added to a mine's current light duty fleet, thus accelerating the turnover to a newer generation of technology.

(5) Is there a summary of the applicable requirements and effective dates?

All of the emissions standards established by MSHA's final rule are summarized in Table I–1.

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Table I-1

Type of Equipment	Emissions Limit	When Applicable (from date final rule published)
Permissible		
newly introduced	2.5 grams per hour	60 days
existing fleet	2.5 grams per hour	18 months
Heavy duty nonpermissible		
newly introduced	5.0 grams per hour	60 days
existing fleet (interim)	5.0 grams per hour	30 months
existing fleet (final)	2.5 grams per hour	4 years
Generators and compressors	same as heavy duty	same as heavy duty
Other light duty nonpermissible		
newly introduced	5.0 grams per hour (or listed EPA standards)	60 days
entire fleet	no requirements	

BILLING CODE 4510–43–C

(6) What other requirements are contained in the final rule for underground coal mines?

Miners have to be trained annually in the risks of dpm exposure and in control methods being used at the mine. Also, certain information about diesel engines and aftertreatment devices has to be added to the mine ventilation plan. The paperwork requirements added by this rule are small—on average, less than 7 hours in the first year and 4 hours per year thereafter for a mine operator that uses diesel powered equipment. Furthermore, manufacturers of diesel powered equipment will incur burden hours only during the first year that the rule is in effect in order to amend existing MSHA approvals. During the first year that the rule is in effect the average manufacturer will incur 70 paperwork burden hours.

(7) Will the final rule eliminate any health risks to miners resulting from the use of diesel powered equipment underground?

Although the Agency expects that health risks will be substantially reduced by this rule, the best available evidence indicates that a significant risk of adverse health effects due to dpm exposures will remain after the rule is fully implemented.

MSHA considered establishing stricter standards for certain types of equipment, and covering more light duty equipment, but concluded that such actions would either be technologically or economically infeasible for the coal mining industry as a whole at this time. As MSHA takes actions to facilitate the introduction of newer and cleaner engines underground, and as control technologies continue to develop, additional reductions in dpm levels may become feasible for the industry as a whole. MSHA will continue to monitor developments in this area.

(8) What are the costs and benefits of the final rule?

Costs

Table I–2 summarizes the compliance costs to mine operators that use diesel powered equipment for each section of the rule; total compliance costs are about $7 million a year. Table I–3 summarizes the compliance costs to mine operators that use diesel powered equipment by mine size (*i.e.,* mines employing fewer than 20 workers, mines employing between 20 and 500 workers, and mines employing more than 500 workers). In addition, there is a total annualized cost to diesel equipment manufacturers of $30,030.

MSHA's full Regulatory Economic Analysis, (REA) from which Tables I–2 and I–3 are derived, provides considerable detail on the assumptions MSHA used in developing these cost estimates, and on the costs associated with the controls required for particular engines in the current fleet. For example, MSHA is estimating that for a Caterpillar 3304 PCNA in a heavy duty piece of equipment, an operator will have to spend about $4,500 a year to achieve compliance with the limits for that equipment (hot gas filter, cost annualized, plus annual costs of regeneration). Copies of MSHA's full (REA) analysis are in the record and are available to the mining community upon request.

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Table I-2:
Total Yearly Compliance Costs for Mine Operators

Requirement	Total Yearly Industry Cost
Section 72.500 (Permissible Equipment)	$ 4,468,965
Section 72.501 (Heavy Duty Equipment)	$ 2,278,970
Section 72.502 (Light Duty Equipment)	$ 121,391
Section 72.503 (Filter Maintenance Training)	$ 2,971
Section 72.510 (Miner Health Training)	$ 196,209
Section 75.520 (Diesel Equipment Inventory)	$ 2,327
TOTAL	$ 7,070,833

Table I-3:
Total Cost By Mine Size Class

	Number of Employees		
	< 20	20 to 500	> 500
Compliance Costs	$7,411	$6,087,732	$975,690

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Benefits

Benefits of the rule include reductions in lung cancer. In the long run, as the mining population turns over, MSHA estimates that a minimum of 1.8 lung cancer deaths will be avoided per year.[1]

Benefits of the rule will also include reductions in the risk of death from cardiovascular, cardiopulmonary, or respiratory causes and in sensory irritation and respiratory symptoms. MSHA does not believe that the available data can support reliable or precise quantitative estimates of these benefits. Nevertheless, the expected reductions in the risk of death from cardiovascular, cardiopulmonary, or respiratory causes appear to be significant, and the expected reductions in sensory irritation and respiratory symptoms appear to be rather large.

(9) What actions has MSHA taken, and what additional actions does it plan to take, to facilitate compliance with this rule?

This rule is a continuation of efforts by MSHA to help the mining community deal with the use of diesel engines in mining. The diesel equipment rule, now in effect, has itself contributed to the reduction of diesel exhaust emissions through the use of low sulfur diesel fuel, the requirement that all engines underground be approved, and improved maintenance. In one case, testimony was presented by a mine operator that timely engine maintenance, triggered by the weekly undiluted exhaust emissions test required by the new regulation, has greatly reduced carbon monoxide emissions from diesel equipment. These properly tuned engines will generate less particulate. MSHA has devoted workshops specifically to dpm control, issued a Toolbox of control methods to assist the mining community in this regard, and developed a computerized Estimator to help individual mines evaluate the impact of alternative approaches of controlling dpm emissions. The agency has verified the efficiency of the current generation of paper filters, and has sponsored work on the measurement of dpm in ambient mine atmospheres.

This final rule includes certain provisions to facilitate compliance—*e.g.,* authorizing MSHA to rely on the testing requirements of organizations like VERT, and permitting compliance with certain EPA requirements to be deemed as compliance with the requirements in this rule for newly introduced light duty equipment. The agency is, as described above, planning to take action in consultation with the mining community to facilitate the approval, and in particular the approval for permissible use, of a newer, cleaner generation of diesel engines. The agency will be preparing a compliance guide for this rule, and posting a variety of useful information on its web site. If necessary, additional workshops may be scheduled. In addition, MSHA is ready to provide special technical assistance to those who are planning to bring new engines or equipment underground in the next few months.

(10) Are surface mines addressed in this rule?

Surface areas of underground mines, and surface mines, are not covered by this rule. In certain situations the concentrations of dpm at surface mines may be a cause for concern: *e.g.,* production areas where miners work in the open air in close proximity to loader-haulers and trucks powered by older, out-of-tune diesel engines, shops, or other confined spaces where diesel engines are running. The Agency believes, however, that these problems are currently limited and readily controlled through education and technical assistance. The Agency would like to emphasize, however, that surface miners are entitled to the same level of protection as other miners; and the Agency's risk assessment indicates that even short-term exposures to concentrations of dpm like those observed may result in serious health problems. Accordingly, in addition to providing education and technical assistance to surface mines, the Agency will also continue to evaluate the hazards of diesel particulate exposure at surface mines and will take any necessary action, including regulatory action if warranted, to help the mining community minimize any hazards.

II. Background Information

This part provides the context for this preamble. The nine topics covered are:

(1) The role of diesel-powered equipment in underground coal mining in the United States;

(2) The composition of diesel exhaust and diesel particulate matter (dpm);

(3) The difficulties in measuring ambient dpm in underground coal mines;

(4) Limiting the public's exposure to diesel and other fine particulates—ambient air quality standards;

(5) The impact on emissions of MSHA approval standards and environmental tailpipe standards;

(6) Methods for controlling dpm emissions in underground coal mines;

(7) Existing standards for underground coal mines that limit miner exposure to diesel emissions;

(8) Information on how certain states are restricting occupational exposure to diesel particulate matter; and

(9) A history of this rulemaking.

Material on these subjects which was available to MSHA at the time of the proposed rulemaking was included in Part II of the preamble that accompanied the proposed rule (63 FR 17501 *et seq.*). This version has been updated to reflect the record, to discuss certain issues relevant to underground coal mines in more detail, and reorganized as appropriate.

(1) The Role of Diesel-Powered Equipment in Underground Coal Mining in the United States

Diesel engines, first developed about a century ago, now power a full range of mining equipment. However at this time, less than 20% of underground coal mines (fewer than 150 underground coal mines) utilize this technology. Equipment powered by other sources (electrical power delivered by cable or trolley, and battery power) continues to predominate in this mining sector. Moreover, unlike in other mining sectors, most of the current diesel fleet in underground coal mines consists of light-duty support vehicles, and only limited numbers of the equipment used in digging or hauling coal is powered by diesel engines.

Many in the mining industry believe that diesel-powered equipment has productivity and safety advantages over equipment powered by other sources. Others cite evidence to the contrary, and several key underground coal mining states continue to ban or significantly restrict the use of diesel-powered equipment in underground coal mines. The use of diesel engines to power equipment in underground coal mining is increasing and appears likely to continue to do so absent significant improvement in other power technologies.

Historical Overview of Diesel Power Use in Mining. As discussed in the notice of proposed rulemaking, the diesel engine was developed in 1892 by the German engineer Rudolph Diesel. It was originally intended to burn coal dust with high thermodynamic efficiency. Later, the diesel engine was modified to burn middle distillate petroleum (diesel fuel). In diesel engines, liquid fuel droplets are injected

[1] This lower bound figure could significantly underestimate the magnitude of the health benefits. For example, the estimate based on the mean value of all the studies examined is 13 lung cancer deaths avoided per year.

into a prechamber or directly into the cylinder of the engine. Due to compression of air in the cylinder the temperature rises high enough in the cylinder to ignite the fuel.

The first diesel engines were not suited for many tasks because they were too large and heavy (weighing 450 lbs. per horsepower). It was not until the 1920's that an efficient lightweight diesel power unit was developed. Since diesel engines were built ruggedly and had few operational failures, they were used in the military, railway, farm, construction, trucking, and busing industries. The U.S. mining industry was slow to begin using these engines. Thus, when in 1935 the former U.S. Bureau of Mines published a comprehensive overview on metal mine ventilation (McElroy, 1935), it did not mention ventilation requirements for diesel-powered equipment. By contrast, the European mining community began using these engines in significant numbers, and various reports on the subject were published during the 1930's. According to a 1936 summary of these reports (Rice, 1936), the diesel engine had been introduced into German mines by 1927. By 1936, diesel engines were used extensively in coal mines in Germany, France, Belgium and Great Britain. Diesel engines were also used in potash, iron and other mines in Europe. Their primary use was in locomotives for hauling material.

It was not until 1939 that the first diesel engine was used in the United States mining industry, when a diesel haulage truck was used in a limestone mine in Pennsylvania, and not until 1946 was a diesel engine used in coal mines. Today, however, diesel engines are used to power a wide variety of equipment in all sectors of U.S. mining. Production equipment includes vehicles such as haultrucks and shuttle cars, load-haul-dump units, face drills, and explosives trucks. Diesel engines are also used in support equipment including generators and air compressors, ambulances, crane trucks, ditch diggers, foam machines, forklifts, graders, locomotives, longwall component carriers, lube units, mine sealant machines, personnel carriers, hydraulic power units, rock dusting machines, roof drills, tractors, utility trucks, water spray units, and welders.

Current Patterns of Diesel Power Use in Underground Coal Mining. The underground coal mining sector is not as reliant upon diesel power as are other mining sectors. While nearly all underground metal and nonmetal mines, and nearly all surface mines, use diesel-powered equipment, less than 20% of underground coal mines use it. Table II–1 provides further information on the current inventory.

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Table II-1. Diesel Equipment in Underground Coal Mines

Mine size	# Mines	# Mines w/Diesel	# Engines
Small[a]	382	7	20
Large	528	138	3,101
All	910	145	3,121

Notes on Table II-1:
(a) A "small" mine is one with less than 20 miners.

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The great majority of the diesel engines used in underground coal mines are used to power support equipment, rather than production equipment. This is in sharp contrast to other sectors. For example, in underground metal and nonmetal mines, of the approximate 4,100 pieces of diesel equipment normally in use at the time of MSHA's proposal, nearly half of the units were estimated to be used for loading and hauling. By contrast, of the approximately 3,000 pieces of diesel equipment in use in underground coal mines, MSHA estimates that fewer than 10% are used for coal loading and haulage. Moreover, because of space constraints and other operating conditions in underground coal mines, virtually all coal loading and hauling equipment has engines less than 200 horsepower; by contrast, virtually all such equipment in metal and nonmetal mines has engines greater than 200 horsepower and ranging to more than 750 horsepower or greater. As a result, the average horsepower of diesel engines powering equipment in underground coal mines is much less than the average engine in underground metal and nonmetal mines and all surface mines. This is significant because, other things being equal, lower horsepower engines are going to produce less dpm emissions by mass than higher horsepower engines.

The engines in underground coal mines can be divided into three categories recognized under existing MSHA regulations: "permissible", "heavy-duty nonpermissible", and "light-duty nonpermissible." In this final dpm rule, MSHA is establishing different requirements for each of these categories. Accordingly, some background on this categorization is needed.

Use of Diesel Engines in Permissible Equipment. Under existing regulations, equipment, whether powered by diesel engines or electricity, that is used in areas of the mine where methane gas is likely to be present in dangerous concentrations must be MSHA-approved "permissible" equipment.

Permissible diesel powered equipment for use in coal mines is provided with special equipment to prevent the ignition of methane. This special equipment includes flame arresters and special treatment of flanges and joints. Since diesel engines normally have very hot surface temperatures and hot exhaust gas that can constitute an ignition source, permissible diesels must be provided with a means to maintain the temperatures of surfaces and the exhaust gas below 302°F.

MSHA regulations are very specific in defining those areas of the mine where permissible equipment is required. Generally, permissible equipment is required where the coal mining is actually being performed, because the mining process typically liberates methane. These areas are commonly referred to as ''inby'' areas. In some cases, however, permissible equipment is required to be used in other areas of the mine. For example, only permissible diesel-powered equipment may be used in return aircourses. The permissible equipment provides an additional level of fire protection because of the strict temperature controls on the equipment surface and exhaust. This increased protection is required because of the potential for the accumulation of dangerous levels of methane in these aircourses.

MSHA's January 2000 inventory indicates that of the 3,121 diesel powered pieces of equipment in underground coal mines, 528 units are permissible pieces. The emissions generated by permissible equipment make a significant contribution to dpm concentrations in the mines where they are functioning. This is because the equipment has large engines, works hard and continuously in locations generally far from ventilation sources, and in close quarters with miners.

Moreover, the engines which have to date been approved for permissible use are among those which emit the highest levels of dpm (in grams/hour): the Caterpillar 3304, Caterpillar 3306 (available in two horsepower sizes), the Deutz D916–6, and the Isuzu QD–100. The Deutz D916–6 is still used in underground coal mines, however, it is no longer in production. MSHA recently approved the Caterpillar 3306PCTA permissible, the first approved turbocharged engine.

Diesel engines in the horsepower ratings required to power permissible equipment are now available in new low emissions technology engines. However, none of them has been approved for use on permissible equipment because no applications for MSHA approval have been received. This situation may reflect a lack of adequate incentives for engine and equipment manufacturers to incur the development costs to meet MSHA permissibility requirements or to pay the fees required for approval.

MSHA is developing programs that would facilitate the availability of engines that utilize the latest technologies to reduce gaseous and particulate emissions for use in permissible equipment. Current engine designs that utilize low emissions technologies are currently approved by MSHA in nonpermissible form.

One of the programs that MSHA is considering would follow the precedent established in the recently published diesel equipment rule. To facilitate compliance with this dpm rule, MSHA is considering funding the additional emissions testing needed to gain permissibility approval, previously approved, non-permissible engines that utilize low emissions technology engines, or waiving the normal fees that the Agency charges for the administrative and technical evaluation portion of the approval process.

Alternatively, MSHA may relax, as an interim measure, the requirement that engine approvals be issued only to engine manufacturers. Under this program an equipment manufacturer could utilize an engine, approved by MSHA as nonpermissible, in a permissible power package. MSHA would ensure that the additional emissions tests required for permissible engines are conducted as part of the power package approval process. Provisions of the two programs could be combined.

While the availability of cleaner engines would help reduce the dpm emissions from the permissible fleet, there are aftertreatment filters available for such equipment that are both highly efficient and relatively low cost. As discussed in more detail in section 6 of this part, because the exhaust temperature of these permissible pieces of equipment must be cooled for safety reasons, aftertreatment devices whose filtration media consists of paper can be directly installed on this equipment. Paper filters exposed to uncooled exhaust pose a fire and ignition hazard.

Use of Diesel Engines in Nonpermissible Equipment. In those areas of an underground coal mine where methane concentrations can be limited through the control of ventilation air, permissible equipment is not required. Generally, this is the case in areas away from the face, often referred to as ''outby'' areas. Most equipment operating in underground coal mines is ''nonpermissible'' equipment.

Nonpermissible equipment is divided into several categories for purposes of the diesel equipment rules that currently apply in underground coal mines (30 CFR part 75). In pertinent part, those rules provide:

§ 75.1908 Nonpermissible diesel-powered equipment; categories

(a) Heavy-duty diesel-powered equipment includes—

(1) Equipment that cuts or moves rock or coal;

(2) Equipment that performs drilling or bolting functions;

(3) Equipment that moves longwall components;

(4) Self-propelled diesel fuel transportation units and self-propelled lube units; or

(5) Machines used to transport portable diesel fuel transportation units or portable lube units.

(b) Light-duty diesel-powered equipment is any diesel-powered equipment that does not meet the criteria of paragraph (a) * * *

(c) * * *.

(d) Diesel-powered ambulances and fire fighting equipment are a special category of equipment that may be used underground only in accordance with the mine fire fighting and evacuation plan * * *.

MSHA's inventory indicates that of the 3,121 diesel powered pieces of equipment, 497 are heavy duty nonpermissible pieces, 66 are generators and air compressors, and 2,030—that is, about two-thirds of the total underground coal diesel fleet at present—are other light duty nonpermissible pieces.

The rationale for the division of nonpermissible dieselized equipment into these classes requires some background here because in this rulemaking on dpm, MSHA proposed making a significant distinction between the requirements applicable to each class.

The division resulted from MSHA's 1996 regulation establishing safety rules for the use of dieselized equipment in underground coal mines (the general history and purpose of which are summarized in section 9 of this Part). As discussed in the preamble to the final diesel safety rule (61 FR 55459–61), the purpose of the categorization was to take the diversity of nonpermissible equipment into account in establishing regulatory requirements relevant to safety. The final categorization scheme for nonpermissible equipment developed over the course of time in response to public comments to the proposed rule.

Equipment falling within the heavy duty category is typically used for extended periods during a shift on a continuous, rather than an intermittent, basis. Heavy duty equipment also moves heavy loads or performs considerable work. Accordingly, to ensure such equipment could operate in a safe manner, the safety rule required that each piece of heavy duty equipment:

> * * * has to be equipped with an automatic fire suppression system addressing the additional fire risks resulting from the way this equipment is used. Heavy-duty equipment also produces greater levels of gaseous contaminants, and under the final rule is therefore subject to weekly undiluted exhaust emissions tests * * * and is included in the air quantity calculation of ventilation of diesel-powered equipment * * *. (61 FR 55461)

It is important to note that there are other types of underground coal mining equipment which, although they have operating characteristics much like heavy duty equipment, were not designated as such under the diesel equipment rule. That is because such equipment (*e.g.,* generators and compressors) is considered as portable equipment and special requirements were established in that rule to address the hazards presented by that equipment.

Ambulances and fire-fighting equipment which use diesel engines have operating characteristics like light-duty equipment, but under the diesel equipment rule are considered a special category of equipment that does not have to meet the requirements of that rule. The equipment in this category must only be used in emergencies or fire drills and in compliance with fire fighting and evaluation plan requirements. Consequently, such equipment is not required to have an approved engine or power package or comply with the design and performance requirements of §§ 75.1909 and 75.1910 (61 FR 55461).

Under the diesel equipment rule, heavy-duty equipment may be used to perform light-duty work; but equipment that is classified as light-duty may not be used, even intermittently, to perform the functions listed in paragraphs (a)(1) through (a)(5) of 30 CFR 75.1908 because it is not required to have the automatic fire suppression system that MSHA determined was necessary for such kinds of work. (Id.) As noted in the preamble, two machines of the same model could fall into different equipment categories depending on how they are used. Although of the same design, they do not present the same risk of fire because of the way in which they are used, nor do they produce the same quantities of exhaust contaminants:

> ''* * * machines that are operated for extended periods of time under heavy load generate more contaminants than machines that are not.'' (Id.)

It was for this reason—the rate of contaminant generation—that in proposing a rule to limit the concentration of dpm in underground coal mines, MSHA proposed making a distinction between heavy-duty equipment and light-duty equipment. MSHA proposed requiring heavy-duty nonpermissible equipment and permissible equipment to be equipped with filters capable of removing 95% of the dpm emitted by the engines in those pieces of equipment. The proposal did not include any controls for the dpm emitted from light-duty equipment nor for ambulances and fire-fighting equipment. As noted in section 9 of this part, the Agency asked the mining community to comment on the Agency's assumptions and consider some options in this regard. The record on this matter and MSHA's final decision are discussed in Part IV.

Whether categorized as heavy-duty or light-duty, the engine exhaust from nonpermissible equipment is not required to be cooled for safety reasons like exhaust from permissible equipment. Accordingly, this means that paper-type filters cannot be added directly to nonpermissible equipment without first adding a water scrubber or heat exchanger; otherwise, the paper would burn. As a result, control devices that are designed to filter hot exhaust gases (*e.g.,* ceramic filters) provide a cost effective alternative for dpm control with nonpermissible equipment.

Does Diesel Power Have Advantages Over Alternative Sources of Power for Equipment Used in Underground Coal Mines? As pointed out by a commenter, a number of power sources for mining equipment have been tried in the mining industry only to be rejected for various reasons (*e.g.,* gasoline engines, cables, and compressed air). Today, this commenter continued, there are three general ways of powering mining equipment: electric power (delivered by electric trailing cables or by trolley wires), on-board battery power, and diesel. Table II–2 reproduces a list provided by this commenter as to his view of some of the ''advantages and challenges'' of these power sources; MSHA is reproducing this list as a convenient summary, but does not necessarily agree or disagree with each specific entry.

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Table II-2
One Commenter's Comparison of Power Sources

Power Type	Electric w/trailing cable	Electric w/trolley wire	Battery	Diesel
Necessary infra-structure	electric power centers must be available at all areas where this type of electric trailing cable equipment is used	trolley wires and rails must be available at all areas where electric trolley wire equipment is used	battery charging stations must be available within the operating range of all battery powered equipment	refueling stations must be available within the operating reach of all diesel powered equipment
Availability of power source	the machine must be within reach and tethered to the electric power center	the machine must be connected to the energized electric trolley wire	the machine must be within reach of the charging station once the battery is depleted, usually at least once a shift	the vehicle is driven to a refueling station or a refueling vehicle is driven to the vehicle - refueling is typically performed every 1-3 shifts
Mobility	the range is limited by the reach of the trailing capable and is usually less than 500 feet	limited to areas with energized trolley wires	good as long as the battery is charged, weak when the battery charge is low	excellent and unlimited mobility in all properly ventilated areas of the mine
Operating time between service	uninterrupted until the trailing cable extent has been reached	uninterrupted as long as operating within reach of the trolley wire	may be less than a shift - multiple batteries are normally needed	at least one full shift, often several shifts
Safety concerns	electrocution hazard from damaged energized cables, back injuries from lifting and moving heavy cables	electrocution hazard from contact with energized trolley wires, open sparks	fire hazard during recharging the batteries; battery acid spills, hydrogen release	fuel spills, health concerns, acid exhaust emissions
Conclusions	prone to back injuries and electrocution risk	hazardous and prone to electrocution risk	prone to fire risk	requires emission controls

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Some in the mining industry strongly favor the use of diesel engines to power equipment in underground coal mines. A representative of a company with four underground coal mines testified that it has 200 pieces operated by diesel power, and is continuing to add more. Another commenter stated that diesel is the power source of choice for moving personnel and supplies in large underground mines where coal is moved by conveyor belt.

A number of commenters asserted that diesel-powered equipment has productivity and safety advantages over electrically-powered and battery-powered equipment.

One commenter argued that diesel reduces the risks associated with the use of electrical equipment by eliminating the need for trolley wires, trolley poles and trailing cables that cause injuries, accidents and fatalities—shocks, electrocutions, burns, fires, tripping or being struck by trolley poles, and also reduce the number of material handling injuries. This commenter also argued that unlike electrical power, diesel use does not restrict mining plans or the mining cycle because operations are not hampered by cable length or time consuming power moves, provide greater flexibility in underground travel routes, and make equipment moves from one area of a mine to another more efficient. This commenter further claimed that compared to battery-powered mining equipment (which arguably provides the same flexibility), diesels can haul coal more efficiently over longer distance, provide more power, and eliminate time-consuming battery change-out time.

Another commenter noted the increased potential for fatalities and injuries in underground coal mines when trolley wires are present, and further that trolley wires restrict ventilation in one entry.

Another commenter noted the difficulties of evacuating miners in the event of emergencies over the large distances in some underground mines using sources of power that were more prone to failure than diesel.

Another commenter asserted that all of the 18 employees who had died since 1972 as a result of exposed overhead direct current trolley lines could have lived if diesel power had been in use, and pointed to examples of fires initiated by trolley wires with associated loss of productivity. This commenter also noted that battery powered equipment has been known to cause injuries, and explosions both from its production of hydrogen gas and from sparks igniting methane in the mine atmosphere.

Commenters also note that many asserted safety risks associated with the use of diesel powered equipment in underground coal mines have now been addressed as a result of MSHA's safety rules.

Other commenters, however, pointed out that there are a number of the nation's most productive underground coal mines (including both those using longwall and those using room and pillar mining techniques) which do not use this technology. These commenters challenged industry claims that diesel power is necessary for business to survive. Some also noted that miners are trained to protect themselves better from safety hazards that accompany the use of electrical power, like tripping on cables and electrical hazards, but are not able to protect themselves from health hazards they cannot see. In this regard, the hearing transcripts are replete with reminders by underground coal miners of their concern about what they are breathing in light of the tragic experience with black lung disease.

As indicated by MSHA in the preamble to the proposed rule (63 FR 17503), not many studies done recently address the contentions that diesel power provides safety and/or productivity advantages, and the studies which have been reviewed by MSHA do not clearly support this hypothesis.

Outlook for Use of Diesel Engines To Power Equipment in Underground Coal Mines

The use of diesel engines to power equipment in underground coal mining is increasing. In fact, since this rulemaking was proposed, MSHA's inventory has recorded an increase of about 5% in the number of diesel-powered pieces of equipment at the roughly 145 coal mines using diesel power underground. This trend appears likely to continue, absent significant improvement in other power technologies.

Several key underground coal mining states—Ohio, Pennsylvania and West Virginia—continue to ban or significantly restrict the use of diesel-powered equipment in underground coal mines (as discussed in section 8 of this Part). There are 339 underground coal mines in these states. If the current restrictions in these States were relaxed, in accordance with the expressed interest of industry groups toward this end, many of these underground coal mines are likely to begin using diesel to power some equipment.

Full implementation of MSHA's recent rules for the safe use of diesel-powered equipment in underground coal mines (discussed in section 7 of this part), is also likely to lead to increased diesel use because they resolve certain safety concerns that discouraged the mining community from using such equipment more widely. Another factor suggesting that the use of diesel power will expand is that both miners and mine operators are concerned about the future of their industry.

On the other hand, operators as well as miners have acknowledged that potential health hazards associated with the use of diesel power must be addressed if its use is to become widespread. Although the Agency expects that health risks will be substantially reduced by this rule, the best available evidence indicates that a significant risk of adverse health effects due to dpm exposures will remain after the rule is fully implemented. As explained in Part V of this preamble, however, MSHA has concluded that the underground coal mining sector as a whole cannot feasibly reduce dpm concentrations further at this time. Nevertheless, the efforts by US and overseas environmental regulators to restrict dpm and other diesel emissions into the environment, discussed in sections 4, 5 and 6 of this Part, are leading to technological improvements in engines, fuel and filters that will help reduce this risk.

Currently, diesel power faces only a limited number of competitive power sources. It is unclear how quickly new ways to generate energy to run mobile vehicles will be available for use in underground mining activities. New hybrid electric automobiles have been introduced this year by two manufacturers (Honda and Toyota); these vehicles combine traditional internal combustion power sources (in this case gasoline) with electric storage and generating devices that can take over during part of the operating period. By reducing the time the vehicle is directly powered by combustion, such vehicles reduce emissions. Further developments in electric storage devices (batteries), and chemical systems that generate electricity (fuel cells) are being encouraged by government-private sector partnerships. For further information on recent developments, see the Department of Energy alternative fuels web site at http://www.afdc.doe.gov/altfuels.html., and "The Future of Fuel Cells" in the July 1999 issue of *Scientific American.* Until such new technologies mature, and are reviewed for safe use underground, MSHA assumes that the mining community's interest in the use underground of diesel-power as an alternative to direct electric power is likely to continue.

(2) The Composition of Diesel Exhaust and Diesel Particulate Matter (DPM)

The emissions from diesel engines are actually a complex mixture of compounds, containing gaseous and particulate fractions. The specific composition of the diesel exhaust in a mine will vary with the type of engines used and how they are used. Factors such as type of fuel, load cycle, engine maintenance, tuning, and exhaust treatment will affect the composition of both the gaseous and particulate fractions of the exhaust. This complexity is compounded by the multitude of environmental settings in which diesel-powered equipment is operated. Nevertheless, there are a few basic facts about diesel emissions that are of general applicability.

The gaseous constituents of diesel exhaust include oxides of carbon, nitrogen and sulfur, alkanes and alkenes (*e.g.,* butadiene), aldehydes (*e.g.,* formaldehyde), monocyclic aromatics (*e.g.,* benzene, toluene), and polycyclic aromatic hydrocarbons (*e.g.,* phenanthrene, fluoranthene). The oxides of nitrogen (NO_X) merit particular mention because in the atmosphere they can precipitate onto particulate matter. Thus, reducing the emissions of NO_X is a way that engine manufacturers can control particulate production indirectly. (See section 5 of this part).

The particulate components of the diesel exhaust gas include the so-called diesel soot and solid aerosols such as ash particulates, metallic abrasion particles, sulfates and silicates. Most of these particulates are in the invisible sub-micron range of 100nm.

The main particulate fraction of diesel exhaust is made up of very small individual particles. These particles have a solid core consisting mainly of elemental carbon. They also have a very surface-rich morphology. This extensive surface absorbs many other toxic substances, that are transported with the particulates, and can penetrate deep into the lungs. More than 1,800 different organic compounds have been identified as absorbed onto the elemental carbon core. A portion of this hydrocarbon material results from incomplete combustion of fuel; however, most is derived from engine lubrication. In addition, the diesel particles contain a fraction of non-organic adsorbed materials. Figure II–1 illustrates the composition of dpm.

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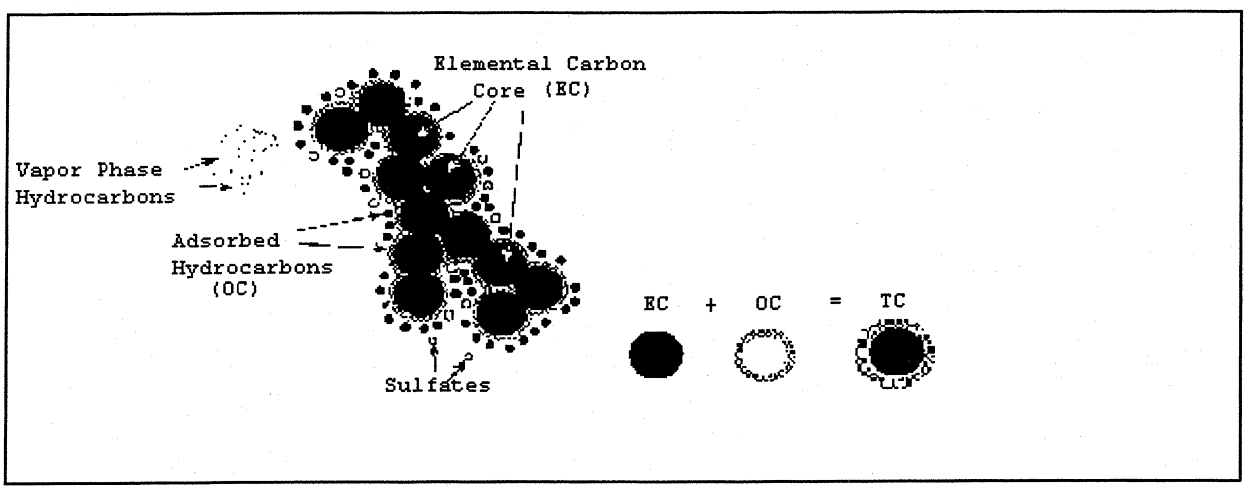
Figure II-1
DPM components



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Diesel particles released to the atmosphere can be in the form of individual particles or chain aggregates (Vuk, Jones, and Johnson, 1976). In underground coal mines, more than 90% of these particles and chain aggregates are submicrometer in size—i.e., less than 1 micrometer (1 micron) in diameter. Dust generated by mining and crushing of material—*e.g.,* silica dust, coal dust, rock dust—is generally not submicrometer in size. Figure II–2 shows a typical size distribution of the particles found in the environment of a mine using equipment powered by diesel engines (Cantrell and Rubow, 1992). The vertical axis represents relative dpm concentration, and the horizontal axis the particle diameter.

As can be seen, the distribution is bimodal, with dpm generally less than 1 μm in size, and dust generated by the mining process greater than 1 μm.

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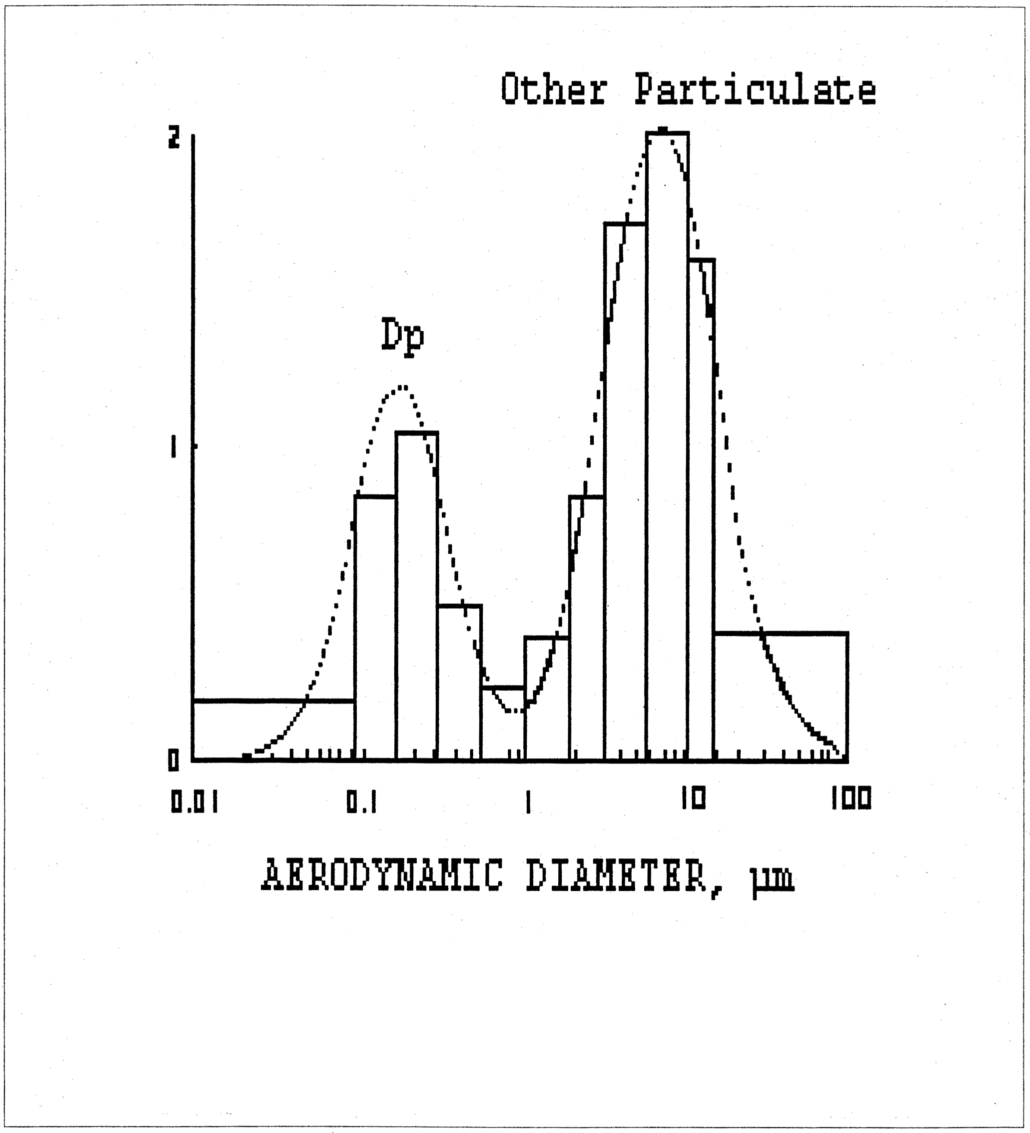
Figure II-2 -Typical distribution of dpm relative to distribution of other mining particulates.



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As shown on Figure II–3 diesel particulates have a bimodal size distribution which includes small nuclei mode particles and larger accumulation mode particles. As further shown, most of diesel particle mass is contained in the accumulation mode but most of the particle number can be found in the nuclei mode.

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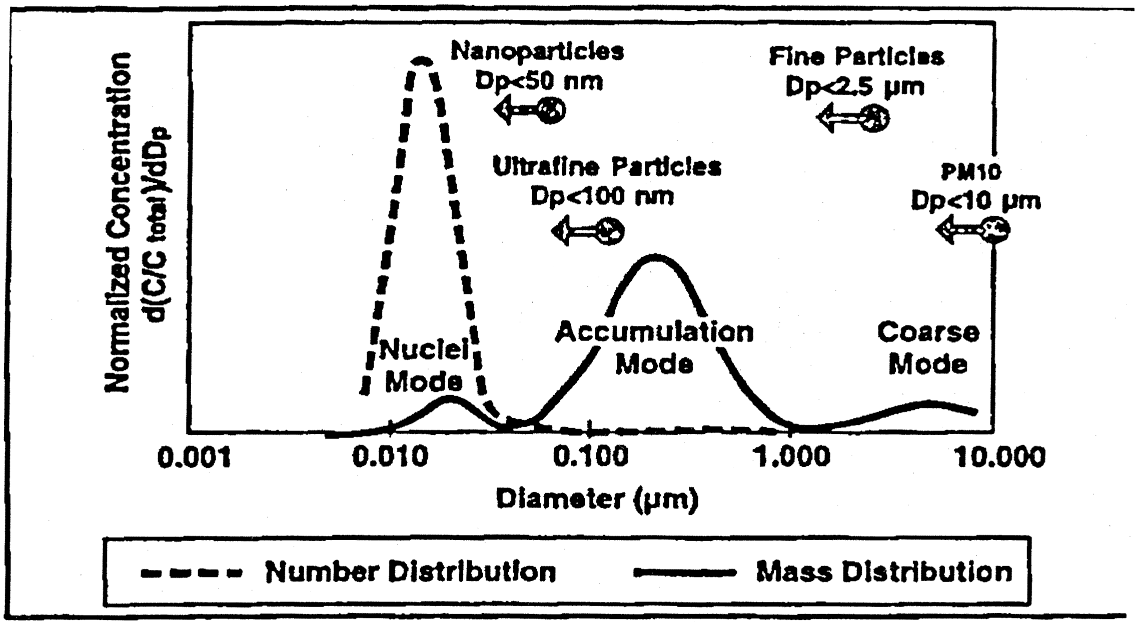
Figure II-3



Diesel particulate size distribution.

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The particles in the nuclei mode, also know as nanoparticles, are being investigated for their health hazard relevance. Interest in these particles has been sparked by the finding that newer ''low polluting'' engines emit higher numbers of small particles than the old engine technology engines. Although the exact composition of diesel nanoparticles is not known, it is thought that they may be composed of condensates (hydrocarbons, water, sulfuric acid). The amount of these condensates and the number of nanoparticles depends very significantly on the particulate sampling conditions, such as dilution ratios, which were applied during the measurement.

Both the maximum particle concentration and the position of the nuclei and accumulation mode peaks, however, depend on which representation is chosen. In mass distributions, the majority of the particulates (*i.e.*, the particulate mass) is found in the accumulation mode. The nuclei mode, depending on the engine technology and particle sampling technique, may be as low as a few percent, sometimes even less than 1%. A different picture is presented when the number distribution representation is used. Generally, the number of particles in the nuclei mode contributes to more than 50% of the total particle count. However, sometimes the nuclei mode particles represent as much as 99% of the total particulate number. The topic of dpm, with particular reference to very tiny particles known as nanoparticles, is discussed further in section 5 of this Part.

(3) The Difficulties of Measuring Ambient DPM in Underground Coal Mines.

As it indicated in its notice of proposed rulemaking to limit the concentrations of dpm in underground coal mines (63 FR 17498, 17500), MSHA decided not to propose a rule to require the measurement of ambient dpm levels in underground coal mines in order to determine compliance. The Agency observed that while there are a number of methods which can measure ambient dpm at high concentrations in underground coal mines with reasonable accuracy. When the purpose is exposure assessment, MSHA does not believe any of these methods provide the accuracy that would be required to measure ambient dpm levels in underground coal mines at lower concentrations.

In particular, MSHA expressed concern about potential difficulties in using the available methods to distinguish between dpm and submicron coal mine dust (63 FR 17506–17507). While the use of an available impactor device can prevent larger particles from entering the sampler (*e.g.,* carbonates), albeit at the expense of eliminating the larger fraction of dpm as well, there are limits on the extent to which it can help MSHA distinguish how much of the fine particulate reaching the sampler is coal dust and how much is dpm. To make the distinction analytically, NIOSH method 5040 would have to be adjusted so that only the elemental carbon is determined. However, as MSHA noted, there are no established relationships between the concentration of elemental carbon and total dpm under various operating conditions. The organic carbon component of dpm can vary with engine type and duty cycle; hence, the amount of whole dpm present for a measured amount of elemental carbon may vary. Accordingly, MSHA concluded that it was ''not confident that there is a measurement method for dpm that will provide accurate, consistent and verifiable results at lower concentration levels in underground coal mines'' (63 FR 17500).

Since there has been no disagreement with MSHA's initial conclusion about the current availability of an accurate, consistent and verifiable method of measuring dpm concentration levels in underground coal mines, the final rule is not dependent on ambient air measurements. MSHA has proposed using such a method for underground metal and nonmetal mines, and the validity of the measurement was the subject of much comment; accordingly, a more complete discussion of this topic will be found in the preamble of the final rule for underground metal and nonmetal mines.

(4) Limiting the Public's Exposure to Diesel and Other Fine Particulates—Ambient Air Quality Standards

Pursuant to the Clean Air Act, the Federal Environmental Protection Agency (EPA) is responsible for setting air pollution standards to protect the public from toxic air contaminants. These include standards to limit exposure to particulate matter. The pressures to comply with these limits have an impact upon the mining industry, which emits various types of particulate matter into the environment during mining operations, and a special impact on the coal mining industry whose product is used extensively in emission-generating power facilities. But those standards hold interest for the mining community in other ways as well, for underlying some of them is a large body of evidence on the harmful effects of airborne particulate matter on human health. Increasingly, that evidence has pointed toward the risks of the smallest particulates—including the particles generated by diesel engines.

This section provides an overview of EPA's rulemaking efforts to limit the ambient air concentration of particulate matter, including its recent particular focus on diesel and other fine particulates. Additional and up-to-date information about the most current rulemaking in this regard is available on an EPA's Web site, http://www.epa.gov/ttn/oarpg/naaqsfin/.

EPA is also engaged in other work of interest to the mining community. Together with some state environmental agencies, EPA has actually established limits on the amount of particulate matter that can be emitted by diesel engines. This topic is discussed in the next section of this Part (section 5). Environmental regulations also establish the maximum sulfur content permitted in diesel fuel used in highway vehicles, and such sulfur content can be an important factor in dpm generation. This topic is discussed in section 6 of this Part. In addition, EPA and some state environmental agencies have also been exploring whether diesel particulate matter is a carcinogen or a toxic material at the concentrations in which it appears in the ambient atmosphere; discussion of these studies can be found in Part III of this preamble.

Background. Air quality standards involve a two-step process: Standard setting by EPA, and implementation by each State.

Under the law, EPA is specifically responsible for reviewing the scientific literature concerning air pollutants, and establishing and revising National Ambient Air Quality Standards (NAAQS) to minimize the risks to health and the environment associated with such pollutants. This review is to be conducted every five years. Feasibility of compliance by pollution sources is not supposed to be a factor in establishing NAAQS. Rather, EPA is required to set the level that provides ''an adequate margin of safety'' in protecting the health of the public.

Implementation of each national standard is the responsibility of the states. Each must develop a state implementation plan that ensures air quality in the state consistent with the ambient air quality standard. Thus, each state has a great deal of flexibility in targeting particular modes of emission (*e.g.,* mobile or stationary, specific industry or all, public sources of emissions vs. private-sector sources), and in what requirements to impose on polluters. However, EPA must approve the state plans pursuant to criteria it establishes, and then take measurements of pollution to determine whether all counties within the state are meeting each ambient air quality standard. An area not meeting an NAAQS is known as a ''nonattainment area''.

Total Suspended Particulates (TSP). Particulate matter originates from all types of stationary, mobile and natural sources, and can also be created from the transformation of a variety of gaseous emissions from such sources. In the context of a global atmosphere, all these particles mix together, and both people and the environment are exposed to a ''particulate soup,'' the chemical and physical properties of which vary greatly with time, region, meteorology, and source category.

The first ambient air quality standards dealing with particulate matter did not distinguish among these particles. Rather, the EPA established a single NAAQS for ''total suspended particulates'', known as ''TSP.'' Under this approach, the states could come into compliance with the ambient air requirement by controlling any type or size of TSP. As long as the total TSP was under the NAAQS—which was established based on the science available in the 1970s—the state met the requirement.

Particulates Less than 10 Microns in Diameter (PM_{10}). When the EPA completed a new review of the scientific evidence in the mid-eighties, its conclusions led it to revise the particulate NAAQS to focus more narrowly on those particulates less than 10 microns in diameter, or PM_{10}. The standard issued in 1987 contained two components: an annual average PM_{10} limit of 50 $\mu g/m^3$, and a 24-hour PM_{10} limit of 150 $\mu g/m^3$. This new standard required the states to reevaluate their situations and, if they had areas that exceeded the new PM_{10} limit, to refocus their compliance plans on reducing the levels of particulates smaller than 10 microns in size. Sources of PM_{10} include power plants, iron and steel production, chemical and wood products manufacturing, wind-blown and roadway fugitive dust, secondary aerosols and many natural sources.

Some state implementation plans required surface mines to take actions to help the state meet the PM_{10} standard. In particular, some surface mines in Western states were required to control the coarser particles—*e.g.,* by spraying water on roadways to limit dust. The mining industry has objected to such controls, arguing that the coarser particles do not adversely impact health, and has sought to have them excluded from the EPA ambient air standards (Shea, 1995; comments of Newmont Gold Company, March 11, 1997, EPA docket number A–95–54, IV–D–2346).

Particulate Less than 2.5 Microns in Diameter ($PM_{2.5}$). The next EPA scientific review was completed in 1996. A proposed rule was published in November of 1996, and, after public hearings and review by the Office of Management and Budget, a final rule was promulgated on July 18, 1997 (62 FR 38651).

The new rule further modifies the standard for particulate matter. Under the new rule, the existing national ambient air quality standard for PM_{10} remains basically the same—an annual average limit of 50 $\mu g/m^3$ (with some adjustment as to how this is measured for compliance purposes), and a 24-hour ceiling of 150 $\mu g/m^3$. In addition, however, the new rule would establish a NAAQS for ''fine particulate matter'' that is less than 2.5 microns in size. The $PM_{2.5}$ annual limit was set at 15 $\mu g/m^3$, with a 24-hour ceiling of 65 $\mu g/m^3$.

The basis for the $PM_{2.5}$ NAAQS was a large body of scientific data indicating that particles in this size range are responsible for the most serious health effects associated with particulate matter. The evidence was thoroughly reviewed by a number of scientific panels through an extended process. The proposed rule resulted in considerable public attention, and hearings by Congress, in which the scientific evidence was further discussed. Moreover, challenges to the EPA's determination that this size category warranted rulemaking were rejected by a three-judge panel of the DC Circuit Court. (*ATA* v. *EPA*, 175 F.3d 1027, D.C. Circuit 1999).

A majority of the DC Circuit Court, however, agreed with challenges to the EPA's determination to keep the existing requirements on PM_{10} as a surrogate for the coarser particulates in this category (those particulates between 2.5 and 10 microns in diameter); instead, the Court ordered EPA to develop a new standard for this size category.

Implications for the Mining Community. As noted earlier in this part, diesel particulate matter is mostly less than 1.0 micron in size. It is, therefore, a fine particulate; in some regions of the country, diesel particulate generated by highway and off-road vehicles constitutes a significant portion of the ambient fine particulate (June 16, 1997, PM–2.5 Composition and Sources, Office of Air Quality Planning and Standards, EPA). As noted in Part III of this preamble, some of the scientific studies of health risk from fine particulates used to support the EPA rulemaking were conducted in areas where the major fine particulate was from diesel emissions. Accordingly, MSHA has concluded that it must consider the body of evidence of human health risk from environmental exposure to fine particulates in assessing the risk of harm to miners of occupational exposure to diesel particulate, and did so in its risk assessment (see part III of this preamble). Comments on the appropriateness of this conclusion by MSHA, are reviewed in Part III.

(5) *The impact on emissions of MSHA approval standards and environmental tailpipe standards.*

MSHA requires that the gaseous emissions from all diesel engines used in underground coal mines meet certain minimum standards of cleanliness; only engines which meet those standards are ''approved'' for use in underground coal mines. The 1996 diesel equipment safety rule required that all engines in the underground mining fleet be approved engines. Thus, these rules set a ceiling for various types of diesel gas emissions. But diesel engines do not have to meet a dpm emissions standard to be ''approved'' for underground use.

Engine emissions of dpm are however, restricted by Federal environmental regulations, supplemented in some cases by State restrictions. Over time, these regulations have required, and are continuing to require, that new diesel engines meet tighter and tighter standards on dpm emissions. As these cleaner engines replace or supplement older engines in underground coal mines, they can lead to a significant reduction in the amount of dpm emitted by the underground fleet.

This section reviews developments in this area. Although this subject was discussed in the preamble of the proposed dpm rule (63 FR 17507), this review here updates the relevant information.

MSHA Approval Requirements for Engines Used in Underground Coal Mines. MSHA requires that all diesel engines used in underground coal mines be ''approved'' by MSHA for such use, and be maintained by operators in approved condition. Among other things, approval of an engine by MSHA ensures that engines exceeding certain pollutant standards are not used in underground coal mines. MSHA sets the standards for such approval, establishes the testing criteria for the approval process, and administers the tests. The costs to obtain approval of an engine are usually borne by the engine manufacturer or equipment manufacturer.

MSHA's 1996 diesel equipment rule (discussed in more detail in section 7 of this Part) made significant changes to diesel engine requirements for underground coal mines. The new rule required the entire underground coal fleet to convert to approved engines no later than November 1999. Accordingly, by the time this rule to limiting dpm exposure goes into effect, all diesel engines in underground coal mines are expected to be approved engines.

The new rule also required that during the approval process the agency determine the particulate index (PI) for the engine. The particulate index (or PI), calculated under the provisions of 30 CFR 7.89, indicates the air quantity necessary to dilute the diesel particulate in the engine exhaust to 1 milligram of diesel particulate matter per cubic meter of air.

Unlike the ventilation rate set for each engine, the PI does not appear on the engine's approval plate (61 FR 55421). Furthermore, the particulate index of an engine is not, under the diesel equipment rule, used to determine whether or not the engine can be used in an underground coal mine.

At the time the diesel equipment rule was issued, MSHA explicitly deferred the question of whether to require engines used in mining environments to meet a specific PI (61 FR 55420–21, 55437). While the matter was discussed during the diesel equipment rulemaking, the approach taken in the final rule was to adopt the multi-level aproach recommended by the Diesel Advisory Committee. This multi-level approach included the requirement to use clean fuel, low emission engines, equipment design, maintenance, and ventilation, all of which are included in the final rule. The requirement for determining the particulate index was included in the diesel equipment rule in order to provide information to the mining community in purchasing equipment—so that mine operators can compare the particulate levels generated by different engines. Mine operators and equipment manufacturers, can use the information along with consideration of the type of machine the engines would power and the area of the mine in which it would be used to make decisions concerning the engine's contribution of diesel particulate to the mine's total respirable dust. Equipment manufacturers can use the particulate index to design and install exhaust after-treatments (61 FR 55421). So that the PI for any engine is known to the mining community, MSHA reports the index in the approval letter, posts the PI and ventilating air requirement for all approved engines on its website, and publishes the index containing its lists of approved engines.

In the proposed dpm rule, MSHA indicated that given that the equipment rule was recently promulgated, it did not yet have enough information to determine the feasibility of a requirement that certain engines meet a specific PI in order to be used underground (63 FR 17564). MSHA received comments on this subject during the hearings and thereafter; the Agency's response to these comments is included in Part IV of this preamble.

Authority for Environmental Engine Emission Standards. The Clean Air Act authorizes the federal Environmental Protection Agency (EPA) to establish nationwide standards for mobile sources of air pollution, including those powered by diesel engines (often referred to in environmental regulations as ''compression ignition'' or ''CI'' engines). These standards are designed to reduce the amount of certain harmful atmospheric pollutants emanating from mobile sources: the mass of particulate matter, nitrogen oxides (which as previously noted, can result in the generation of particulates in the atmosphere), hydrocarbons and carbon monoxide.

California has its own engine emission standards. New engines destined for use in California must meet these standards. The standards are issued and administered by the California Air Resources Board (CARB). In many cases, the California standards are the same as the national standards; as noted herein, the EPA and CARB have worked on certain agreements with the industry toward that end. In other situations, the California standards may be more stringent than federal standards.

Regulatory responsibility for implementation of the Clean Air Act is vested in the Office of Transportation and Air Quality (formerly the Office of Mobile Sources), part of the Office of Air and Radiation of the EPA. Some of the discussion which follows was derived from materials which can be accessed from the agency's home page on the World Wide Web at (http://www.epa.gov/omswww/omshome.htm). Information about the California standards may be found at the CARB home page at (http://www.arb.ca.gov/homepage.htm).

Diesel engines are generally divided into three broad categories for purposes of engine emissions standards, in accordance with the primary use for which the type of engine is designed: (1) Light duty vehicles and light duty trucks (*i.e.,* trucks under 8500 lbs GVWR, which include pick-up trucks and SUVs. EPA has also established a class of ''medium duty passenger vehicles'' which include passenger vehicles over 8500 lbs. These vehicles, mostly large SUVs, are treated like light-duty trucks for the purposes of emission standards; (2) heavy duty highway engines (*i.e.,* those designed primarily to power trucks) greater than 8500 lbs GVWR) which range from the largest pick-up trucks to over the road trucks); and (3) nonroad vehicles (*i.e.,* those engines designed primarily to power small equipment, construction equipment, locomotives, farm equipment and other non-highway uses).

The terms ''heavy duty'' and ''light duty'' are used differently by EPA and MSHA. The category of an engine for purposes of environmental regulations is not the same as the category of mining equipment in which it is used. The engine categories used by EPA have been established with reference to normal transportation uses. But as explained in section 1 of this Part, MSHA has established a classification system for underground coal mining equipment based on how that equipment is used in mining. This system includes ''permissible'' equipment (required where explosive methane gas may be present in significant quantities) and two categories of ''nonpermissible'' equipment known as ''heavy duty nonpermissible'' and ''light duty nonpermissible''. Accordingly, ''heavy duty'' engines might be used in ''light duty'' nonpermissible equipment.

The exact emission standards which a new diesel engine must meet varies with engine category and the date of manufacture. Through a series of regulatory actions, EPA has developed a detailed implementation schedule for each of the three engine categories. The schedule generally forces technology while taking into account certain technological realities.

Detailed information about each of the three engine categories is provided below; a summary table of particulate matter emission limits is included at the end of the discussion.

EPA Emission Standards for Light-Duty Vehicles and Light Duty Trucks. Although vehicle engines in these categories are not currently approved for use in underground coal mines, it might be sought in the future. Accordingly, some information about the applicable environmental regulations is provided here.[2]

Current light-duty vehicles generally comply with the Tier 1 and National LEV emission standards. Particulate-matter emission limits are found in 40 CFR part 86. In 1999, EPA issued new Tier 2 standards that will be applicable to light-duty cars and trucks beginning in 2004. With respect to pm, the new rules phase in tighter emissions limits to parts of production runs for various subcategories of these engines over several years; by 2009, all light duty trucks must limit pm emissions to a maximum of 0.02 g/mi (40 CFR 86.1811–04(c)). Engine manufacturers may, of course, produce complying engines before the various dates required.

EPA Emissions Standards for Heavy-Duty Highway Engines. In 1988, a standard limiting particulate matter emitted from the heavy duty highway diesel engines went into effect, limiting dpm emissions to 0.6 g/bhp-hr. The Clean Air Act Amendments of 1990 and associated regulations provided for phasing in even tighter controls on NO_X and particulate matter through 1998. Thus, engines had to meet ever tighter standards for NO_X in model years 1990, 1991 and 1998; and tighter standards for PM in 1991 (0.25 g/bhp-hr) and 1994 (0.10 g/bhp-hr). The latter remains the standard for PM from these engines for current production runs (40 CFR 86.094–11(a)(1)(iv)(B)). Since any heavy duty highway engine manufactured since 1994 must meet this standard, there is a supply of engines available today which meet this standard. These engines are used in commercial mining pickup trucks.

New standards for this category of engines are gradually being put into place. On October 21, 1997, EPA issued a new rule for certain gaseous emissions from heavy duty highway engines that will take effect for engine model years starting in 2004 (62 FR 54693). The rule establishes a combined requirement for NO_X and Non-methane Hydrocarbon (NMHC). The combined standard is set at 2.5 g/bhp-hr, which includes a cap of 0.5g/bhp-hr for NMHC. EPA promulgated a rulemaking on December 22, 2000 (65 FR 80776) to adopt the next phase of new standards for these engines. EPA is taking an integrated approach to: (a) Reduce the content of sulfur in diesel fuel; and thereafter, (b) require heavy-duty highway engines to meet tighter emission standards, including standards for PM. The purpose of the diesel fuel component of the rulemaking is to make it technologically feasible for engine manufacturers and emissions control device makers to produce engines in which dpm emissions are limited to desired levels in this and other engine categories. The EPA's rule will reduce pm emissions from new heavy-duty engines to 0.01 g/bhp-hr, a reduction from the current 0.1 g/bhp-hr. MSHA assumes it will be some time before there is a significant supply of engines that can meet this standard, and the fuel supply to make that possible.

EPA Emissions Standards for Nonroad Engines. Nonroad engines are those designed primarily to power small portable equipment such as compressors and generators, large construction equipment such as haul trucks, loaders and graders, locomotives and other miscellaneous equipment with non-highway uses. Engines of this type are used most frequently in the underground coal mines to power equipment.

Nonroad diesel engines were not subjected to emission controls as early as other diesel engines. The 1990 Clean Air Act Amendments specifically directed EPA to study the contribution of nonroad engines to air pollution, and regulate them if warranted (Section 213 of the Clean Air Act). In 1991, EPA released a study that documented higher than expected emission levels across a broad spectrum of nonroad engines and equipment (EPA Fact Sheet, EPA420–F–96–009, 1996). In response, EPA initiated several regulatory programs. One of these set Tier 1 emission standards for larger land-based nonroad engines (other than for rail use). Limits were established for engine emissions of

[2] The discussion focuses on the particulate matter requirements for light duty trucks, although the current pm requirement for all light duty vehicles is the same. The EPA regulations for these categories apply to the unit, rather than just to the engine itself; for heavy-duty highway engines and nonroad engines, the regulations attach to the engines.

hydrocarbons, carbon monoxide, NO_X, and dpm. The limits were phased in over model years from 1996 to 2000. With respect to particulate matter, the rules required that starting in model year 1996, nonroad engines from 175 to 750 hp meet a limit on pm emissions of 0.4 g/bhp-hr, and that starting in model year 2000, nonroad engines over 750 hp meet the same limit.

Particulate matter standards for locomotive engines were set subsequently (63 FR 18978, April, 1998). The standards are different for line-haul duty-cycle engine and switch duty-cycle engines. For model years from 2000 to 2004, the standards limit pm emissions to 0.45 g/bhp-hr and 0.54 g/bhp-hr respectively; after model year 2005, the limits drop to 0.20 g/bhp-hr and 0.24 g/bhp-hr respectively.

In October 1998, EPA established additional standards for nonroad engines (63 FR 56968). Among these are gaseous and particulate matter limits adopted for the first time (Tier 1 limits) for nonroad engines under 50 hp. Tier 2 emissions standards for engines between 50 and 175 hp include pm standards for the first time. Further, they establish Tier II particulate matter limits for all other land-based nonroad engines (other than locomotives which previously had Tier II standards). Some of the non-particulate emissions limits set by the 1998 rule are subject to a technology review in 2001 to ensure that the required levels are feasible; EPA has indicated that in the context of that review, it intends to consider further limits for particulate matter. Because of the phase-in of these Tier II pm standards, and the fact that some manufacturers will produce engines meeting the standard before the requirements go into effect, there are or soon will be some Tier II pm engines in some sizes available, but it is likely to be a few years before a full size range of Tier II pm nonroad engines is available.

Table II–3 provides a full list of the EPA required particulate matter limitations on nonroad diesel engines for tier 1 and 2. For example, a nonroad engine of 175 hp produced in 2001 must meet a standard of 0.4 g/hp-hr; a similar engine produced in 2003 or thereafter must meet a standard of 0.15 g/hp-hr.

TABLE II–3.—EPA NONROAD ENGINE PM REQUIREMENTS

kW range	Tier	Year first applicable	PM limit (g/kW-hr)
kW<8	1	2000	1.00
	2	2005	0.80
8≤kW<19	1	2000	0.80
19≤kW<37	1	1999	0.80
	2	2004	0.60
37≤kW<75	1	1998	....
	2	2004	0.40
75≤kW<130	1	1997	....
	2	2003	0.30
130≤kW<225	1	1996	0.54
	2	2003	0.20
225≤kW<450	1	1996	0.54
	2	2001	0.20
450≤kW<560	1	1996	0.54
	2	2002	0.20
kW>560	1	2000	0.54
	2	2006	0.20

The Impact of MSHA and EPA Engine Emission Standards on the Underground Coal Mining Fleet. In the mining industry, engines and equipment are often purchased in used condition, and frequently rebuilt. Thus, many of the diesel engines in an underground coal mine's fleet today may only meet older environmental emission standards, or no environmental standards at all. Although the environmental tailpipe requirements on dpm are already bringing about a reduction in the overall contribution of dpm to the general atmosphere, the beneficial effects of the EPA regulations on mining atmospheres will be slower absent incentive or regulatory actions that accelerate the turnover of mining fleets to engines that emit less dpm. Moreover, while the requirement that all underground coal mine engines be ''MSHA approved'' is leading to a less polluting fleet than would otherwise be the case, there are many approved engines that do emit significant levels of pollution, and in particular dpm. As noted in the discussion of MSHA's approval requirements, the Agency is taking internal actions to ensure that these requirements do not inadvertently slow the introduction of cleaner engine technology.

It should be noted that in theory, underground mines can still purchase certain types of new engines that do not have to meet EPA standards. For example, the current rules on nonroad diesel engines state that they do not apply to engines intended to be used in underground coal and metal and nonmetal mines (40 CFR 89.1(b)). Moreover, it is not uncommon for engine manufacturers to take a model submitted for EPA testing and adjust the horsepower or other features for use in a mining application. In recent years, however, engine manufacturers have significantly cut back on such adjustments because the mining community is not a major market. Accordingly, MSHA believes that most of the diesel engines that will be available for underground mines in the future will meet the applicable EPA standard. In addition, many of the recently approved engines by MSHA currently meet the tier II nonroad pm standards.

The Question of Nanoparticles. Comments received from several commenters on the proposed rule for diesel particulate matter exposure of underground coal miners raised questions relative to ''nanoparticles;'' i.e., particles found in the exhaust of diesel engines that are less than 50 nanometers (nm) in diameter.

One commenter was concerned about recent indications that nanoparticles may pose more of a health risk than the larger particles that are emitted from a diesel engine. This commenter submitted information demonstrating that nanoparticles emitted from the engine could be removed effectively from the exhaust using aftertreatment devices such as ceramic traps.

Another commenter was concerned that MSHA's proposed rule for underground coal mines is based on removing 95% of the particulate by mass. He believed that this reduction in mass was attributed to those particles greater than 0.1µm but less than 1µm and did not address the recent scientific hypothesis that it may be the very small nanopaticles that are responsible for adverse health effects. Based on the recent scientific information on the potential health effects resulting from exposure to nanoparticles, this commenter did not believe that potential the risk of cancer would be reduced if exposure levels to nanoparticles increased. He indicated that studies suggest that the increase in nanoparticles will exceed 6 times their current levels.

Current environmental emission standards established by EPA and CARB, and the particulate index calculated by MSHA, focus on the total mass of diesel particulate matter emitted by an engine—for example, the number of grams per some unit of measure (i.e. grams/brake-horsepower). Thus, the technology under development by the engine industry to meet the standards accordingly focuses on reducing the mass of dpm emitted from the engine. There is some evidence, however, that some aspects of this new technology, particularly fuel injection, is resulting in an increase in the number of nanoparticles emitted from the engine.

Figure II–3, repeated here from section 2 of this Part, illustrates this situation (Majewski, W. Addy, Diesel Progress, June, 1998).

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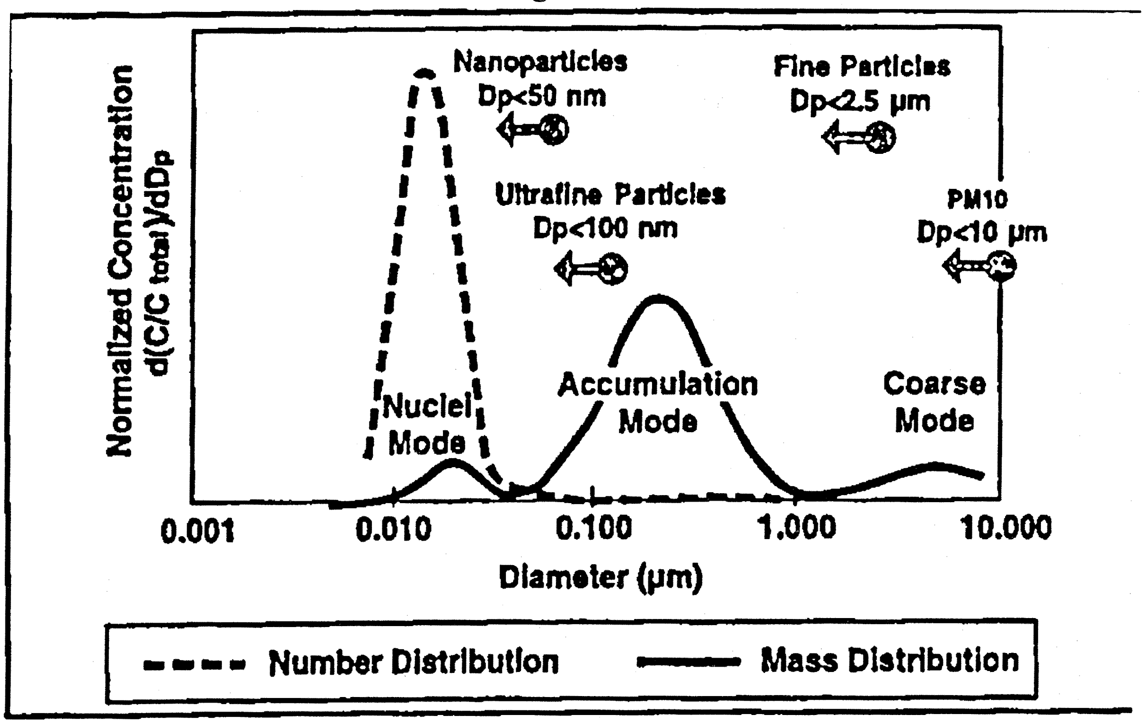
Figure II-3



Diesel particulate size distribution.

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The formation of particulates starts with particle nucleation followed by subsequent agglomeration of the nuclei particles into an accumulation mode. Thus, as illustrated in Figure II–3, the majority of the mass of dpm is found in the accumulation mode, where the particles are generally between 0.1 and 1 micron in diameter. However, when considering the number of particles emitted from the engine, more than half and sometimes almost all of the particles (by number) are in the nuclei mode.

A number of studies have demonstrated that the size of the particles emitted from the newer low emission diesel engines, has shifted toward the generation of nuclei mode particles. One study (cited by Majewski) compared a 1991 engine to its 1988 counterpart. The total PM mass in the newer engine was reduced by about 80%; but the new engine generated thousands of times more particles than the older engine (3000 times as much at 75 percent load and about 14,000 times as much at 25 percent load). One hypothesis offered for this phenomenon is that the cleaner engines produce less soot particles on which particulates can condense and accumulate, and hence they remain in nuclei mode. The accumulation particles act as a "sponge" for the condensation and/or adsorption of volatile materials. In the absence of that sponge, gas species which are to become liquid or solid will nucleate to form large numbers of small particles (see diesel.net technology guide). Mayer, while pointing out that nanoparticle production was a problem with older engines as well, concurs that the technology used to clean up pollution in newer engines is not having any positive impact on nanoparticle production. While there is scientific evidence that the newer engines, designed to reduce the mass of pollutants emitted from the diesel engine, emit more particles in the nuclei mode, quantifying the magnitude of these particles has been difficult. This is because as dpm is released into the atmosphere the diesel particulate undergoes very complex changes. In addition, current sampling procedures produce artificial particulates, which otherwise would not exist under atmospheric conditions. Experimental work conducted at West Virginia University (Bukarski) indicate that nanoparticles are not generated during the combustion process, but rather during other physical and chemical processes which the exhaust undergoes in aftertreatment systems.

While current medical research findings indicate that small particulates, particularly those below 2μm in diameter, may be more harmful to human health than the larger ones, much more medical research and diesel emission studies are needed to fully characterize diesel nanoparticles emissions and their influence on human health. If nanoparticles are found to have an adverse health impact by virtue of size or number, it could require significant adjustments in environmental engine emission regulation and technology. It could also have implications for the type of controls utilized, with some asserting that aftertreatment filters are the only effective way to limit the emission of nanoparticles and others asserting that aftertreatment filters can increase the number of nanoparticles.

As discussed in Part III, the available evidence on the risks for dpm exposure do not currently include enough data to draw conclusions about the risks of exposure to significant numbers of very small particles. Research on nanoparticles and their health effects is currently a topic of investigation. As there have been few measurements of the number of particles emitted (as opposed to mass), it will be very difficult for epidemiologists to extrapolate information in this regard.

Based on the comments received and a review of the literature currently available on the nanoparticle issue, MSHA believes that promulgation of the final rules for underground coal and metal and nonmetal mines is necessary to protect miners. The nanoparticle issues discussed above will not be answered for some time because of the extensive research required to address the questions raised. MSHA's rules will require the application of exhaust aftertreatment devices on nearly all of the most polluting engines. The application of these measures will reduce the number of nanoparticles as well as the mass of the larger particles to which a miner will be exposed—miners wanted aftertreatment on all machines for this purpose.

(6) Other Methods for Controlling DPM in Underground Coal Mines

As discussed in the last section, the introduction of new engines underground will play a significant role in reducing the concentration of dpm in underground coal mines. There are, however, other approaches to reducing dpm concentrations in underground coal mines. Among these are: use of aftertreatment devices to eliminate particulates emitted by an engine; altering fuel composition to minimize engine particulate emission; use of maintenance practices and diagnostic systems to ensure that fuel, engine and aftertreatment technologies work as intended to minimize emissions; enhancing ventilation to reduce particulate concentrations in a work area; enclosing workers in cabs or other filtered areas to protect them from exposure; and use of work and fleet practices that reduce miner exposures to emissions.

As noted in section 9 of this Part, information about these approaches was solicited from the mining community in a series of workshops in 1995, and highlights were published by MSHA as an appendix to the proposed rule on dpm ''Practical Ways to Control Exposure to Diesel Exhaust in Mining—a Toolbox.'' During the hearings and in written comments on this rulemaking, these control methods were discussed.

This section provides updated information on two methods for controlling dpm emissions: aftertreatment devices and diesel fuel content. There was considerable comment on aftertreatment devices because MSHA's proposed rule would have required that certain equipment be equipped with high-efficiency particulate filters; the efficiency of such devices remains an important issue in determining the technological and economic feasibility of the final rule. Moreover, some commenters strongly favored the use of oxidation catalytic converters, a type of aftertreatment device used to reduce gaseous emission but which can also lessen dpm levels. Accordingly, information about them is reviewed here. With respect to diesel fuel composition, a recent rulemaking initiative by EPA, and actions taken by other countries in this regard, are discussed here because of their implications for the mining community.

Emissions aftertreatment devices. One of the most discussed approaches to controlling dpm emissions involves the use of devices placed on the end of the tailpipe to physically trap diesel particulate emissions and thus limit their discharge into the mine atmosphere. These aftertreatment devices are often referred to as ''particle traps'' or ''soot traps,'' but the term filter is also used. The two primary categories of particulate traps are those composed of ceramic materials (and thus capable of handling uncooled exhaust), and those composed of paper materials (which require the exhaust to first be cooled). Typically, the latter are designed for conventional permissible equipment which have water scrubbers installed which cool the exhaust. However, another alternative that is now used in coal mines is ''dry system technology'' which cools the diesel exhaust with a heat exchanger and then uses a paper filter. In addition, ''oxidation catalytic converters,'' devices used to limit the emission of diesel gases, and ''water scrubbers,'' devices used to cool the emission of diesel gases, are discussed here as well, because they also can have effect on limiting particle emission.

Water Scrubbers. Water scrubbers are devices added to the exhaust system of diesel equipment. Water scrubbers are essentially metal boxes containing water through which the diesel exhaust gas passes. The exhaust gas is cooled, generally to below 170 degrees F. A small fraction of the unburned hydrocarbons is condensed and remains in the water with some of the dpm. Tests conducted by the former Bureau of Mines and others indicate that no more than 20 to 30 percent of the dpm is removed. However, MSHA has no definitive evidence on the amount of dpm reduction that can be achieved with a particular water scrubber. The water scrubber does not remove the carbon monoxide, the oxides of nitrogen, or other gaseous emission that remains a gas at room temperature, so their effectiveness as aftertreatment devices is limited.

The water scrubber serves as an effective spark and flame arrester and as a means to cool the exhaust gas. Consequently, it is used in most of the permissible diesel equipment in mining as part of the safety components needed to gain MSHA approval.

The water scrubber has several operating characteristics which keep it from being a candidate for an aftertreatment device on nonpermissible equipment. The space required on the vehicle to store sufficient water for an 8 hour shift is not available on some equipment. Furthermore, the exhaust contains a great deal of water vapor which condenses under some mining conditions creating a fog which can adversely effect visibility. Also, operation of the equipment on slopes can cause the water level in the scrubber to change resulting in water blowing out the exhaust pipe. Control devices can be placed within the scrubber to maintain the appropriate water level. Because these devices are in contact with the water through which the exhaust gas has passed, they need frequent maintenance to insure that they are operating properly and have not been corroded by the acidic water created by the exhaust gas. The water scrubber must be flushed frequently to remove the acidic water and the dpm and other exhaust residue which forms a sludge that adversely effects the operation of the unit. These problems, coupled with the relatively low dpm removal efficiency, have prevented widespread use of water scrubbers as a primary dpm control device on nonpermissible equipment.

Oxidation Catalytic Converters (OCCs). Oxidation catalytic converters (OCCs) were among the first devices added to diesel engines in mines to reduce the concentration of harmful gaseous emissions discharged into the mine environment. OCCs began to be used in underground mines in the 1960's to control carbon monoxide, hydrocarbons and odor (Haney, Saseen, Waytulonis, 1997). Their use has been widespread. It has been estimated that more than 10,000 OCCs have been put into the mining industry over the last several years (McKinnon, dpm Workshop, Beckley, WV, 1995).

Several of the harmful emissions in diesel exhaust are produced as a result of incomplete combustion of the diesel fuel in the combustion chamber of the engine. These include carbon monoxide and unburned hydrocarbons including harmful aldehydes. Catalytic converters, when operating properly, remove significant percentages of the carbon monoxide and unburned hydrocarbons. Higher operating temperatures, achieved by hotter exhaust gas, improve the conversion efficiency.

Oxidation catalytic converters operate, in effect, by continuing the combustion process outside the combustion chamber. This is accomplished by utilizing the oxygen in the exhaust gas to oxidize the contaminants. A very small amount of material with catalytic properties, usually platinum or a combination of the noble metals, is deposited on the surfaces of the catalytic converter over which the exhaust gas passes. This catalyst allows the chemical oxidation reaction to occur at a lower temperature than would normally be required.

For the catalytic converter to work effectively, the exhaust gas temperature must be above 370 degrees Fahrenheit for carbon monoxide and 500 degrees Fahrenheit for hydrocarbons. Most converters are installed as close to the exhaust manifold as possible to minimize the heat loss from the exhaust gas through the walls of the exhaust pipe. Insulating the segment of the exhaust pipe between the exhaust manifold and the catalytic converter extends the portion of the vehicle duty cycle in which the converter works effectively.

The earliest catalytic converters for mining use consisted of alumina pellets coated with the catalytic material and enclosed in a container. The exhaust gas flowed through the pellet bed where the exhaust gas came into contact with the catalyst. Designs have evolved, and now the most common design is a metallic substrate, formed to resemble a honeycomb, housed in a metal shell. The catalyst is deposited on the surfaces of the honeycomb. The exhaust gas flows through the honeycomb and comes into contact with the catalyst.

Soon after catalytic converters were introduced, it became apparent that there was a problem due to the sulfur found in diesel fuels in use at that time. Most diesel fuels in the United States contained anywhere from 0.25 to 0.50 percent sulfur or more on a mass basis. In the combustion chamber, this sulfur was converted to SO_2, SO_3, or SO_4 in various concentrations, depending on the engine operating conditions. In general, most of the sulfur was converted to gaseous SO_2. When exhaust containing the gaseous sulfur dioxide passed through the catalytic converter, a large proportion of it was converted to solid sulphates which are in fact, diesel particulate. Sulfates can "poison" the catalyst, severely reducing its life.

Recently, as described elsewhere in this preamble, the EPA required that diesel fuel used for over the road trucks contain no more than 500 ppm (0.05 percent) sulfur. This action made low sulfur fuel available throughout the United States. MSHA, in its recently promulgated regulations for the use of diesel powered equipment in underground coal mines required that this low sulfur fuel be used. When the low sulfur fuel is burned in an engine and passed through a converter with a moderately active catalyst, only small amounts of SO_2 and additional sulfate based particulate are created. However, when a very active catalyst is used, to lower the operating temperature of the converter or to enhance the CO removal efficiency, even the low sulfur fuel has sufficient sulfur present to create an SO_2 and sulfate based particulate problem. Consequently, as discussed later in this section, the EPA has notified the public of its intentions to promulgate regulations that would limit the sulfur content of future diesel fuel to 15 ppm (0.0015 percent) for on-highway use in 2006.

The particulate removal capabilities of some OCCs are significant in gravimetric terms. In 1995, the EPA implemented standards requiring older buses in urban areas to reduce the dpm emissions from rebuilt bus engines (40 CFR 85.1403). Aftertreatment manufacturers developed catalytic converter systems capable of reducing dpm by 20%. Such systems are available for larger diesel engines common in the underground metal and nonmetal sector. However, as has been pointed out by Mayer, the portion of particulate mass that seems to be impacted by OCCs is the soluble component, and this is a smaller percentage of particulate mass in utility vehicle engines than in automotive engines. Moreover, some measurements indicate that more than 40% of NO is converted to more toxic NO_2, and that particulate mass actually increases using an OCC at full load due to the formation of sulfates. In summation, Mayer concluded that the OCCs do not reduce the combustion particulates, produce sulfate particulates, or have unfavorable gaseous phase reactions increasing toxicity, and that the positive effects are irrelevant for construction site diesel engines. He concludes that the negative effects outweigh the benefits (Mayer).

The Phase 1 interim data report of the Diesel Emission Control-Sulfur Effects (DECSE) Program (a joint government-industry program established to explore lower sulfur content that is discussed in more detail later in this section) similarly indicates that testing of OCCs under certain operating conditions can increase dpm emissions due to an increase in the sulfate fraction. (DECSE Program Summary, Dec. 1999) Another commenter also notes that oxidation catalytic activity can increase sulfates under certain operating temperatures, and that oxidation is a part of aftertreatment systems approaches like the DST® and some ceramic traps. But this commenter asserts that the sulfate production occurs at an operating mode that is seldom seen in real operation.

Other commenters during the rulemaking strongly supported the use of OCCs to reduce particulate and other diesel emissions. They argue that the OCCs result in significant reductions in dpm and in dpm generating gases. One commenter noted that with a clean engine, an OCC might well reduce particulates enough to meet any requirements established by MSHA.

However, another commenter noted that OCCs and ceramic traps can fail when used at higher altitude mines due to the lower oxygen content in the exhaust system. Another commenter asserted that OCCs are not effective at low temperature, although they are improving. Accordingly, this commenter indicated that OCCs have an impact only on light duty equipment when the equipment is working, not when it is idling, and are virtually useless on permissible equipment because of the low exhaust temperatures achieved through cooling. Despite a specific request from MSHA at the rulemaking hearings, no data were provided by OCC advocates to demonstrate that they can perform well at the lower temperatures normally found in light duty equipment.

Hot gas particulate traps. Throughout this preamble, MSHA is referring to the particulate traps (filters) that can be used in the undiluted hot exhaust stream from the diesel engine as hot gas filter. Hot gas filter refers to the current commercially available particulate filters such as ceramic cell, woven fiber filter, sintered metal filter, etc.

Following publication of EPA rules in 1985 limiting diesel particulate emissions from heavy duty diesel engines, development of aftertreatment devices capable of more significant reductions in particulate levels began to be developed for Comerica applications.

The wall flow type ceramic honeycomb diesel particulate filter system was initially the most promising approach (SAE, SP–735, 1988). This consisted of a ceramic substrate encased in a shock-and vibration-absorbing material covered with a protective metal shell. The ceramic substrate is arranged in the shape of a honeycomb with the openings parallel to the centerline. The ends of the openings of the honeycomb cells are plugged alternately. When the exhaust gas flows through the particulate trap, it is forced by the plugged end to flow through the ceramic wall to the adjacent passage and then out into the mine atmosphere. The ceramic material is engineered with pores in the ceramic material sufficiently large to allow the gas to pass through without placing excessive back pressure on the engine, but small enough to trap the particulate on the wall of the ceramic material. Consequently, these units are called wall flow traps.

Work with ceramic filters in the last few years has led to the development of the ceramic fiber wound filter cartridge (SAE, SP–1073, 1995). The ceramic fiber has been reported by the manufacturer to have dpm reduction efficiencies up to 80 percent. This system has been used on vehicles to comply with German requirements that exhaust from all diesel engines used in confined areas be filtered. Other manufacturers have made the wall flow type ceramic honeycomb dpm filter system commercially available to meet the German standard. One commenter noted that a total exhaust, wall-flow, ceramic filter developed in Canada in collaboration with a US firm has been successfully demonstrated underground with a reduction of between 60% and 90% of particulate matter.

The development of these devices has proceeded in response to international and national efforts to regulate dpm emissions. However, due to the extensive work performed by the engine manufacturers on new technological designs of the diesel engine's combustion system, and the use of low sulfur fuel, particulate traps were found to be unnecessary for compliance with the EPA standards of the time for vehicle engines.

These devices proved to be quite effective in removing particulate, achieving particulate removal efficiencies of greater than 90 percent.

It was quickly recognized that this technology, while not immediately required for most vehicles, might be useful in mining applications. The former Bureau of Mines investigated the use of catalyzed diesel particulate filters in underground mines in the United States (BOM, RI–9478, 1993). The study demonstrated that filters could work, but that there were problems associated with their use on individual unit installations, and the Bureau made recommendations for installation of ceramic filters on mining vehicles.

Canadian mines also began to experiment with ceramic traps in the 1980's with similar results (BOM, IC 9324, 1992). Work in Canada today continues under the auspices of the Diesel Emission Evaluation Program (DEEP), established by the Canadian Centre for Mineral and Energy Technology in 1996 (DEEP Plenary Proceedings, November 1996). The goals of DEEP are to: (1) evaluate aerosol sampling and analytical methods for dpm; and (2) evaluate the in-mine performance and costs of various diesel exhaust control strategies.

Reservations regarding their usefulness and practicality remain. One commenter stated at one of the MSHA workshops in 1995, ''while ceramic filters give good results early in their life cycle, they have a relatively short life, are very expensive and unreliable.'' Another commenter reported unsuccessful experiments with ceramic filters in 1991 due to their inability to regenerate at low temperatures, lack of reliability, high cost of purchase and installation, and short life. Another reported that ceramics would not work at higher altitudes because of lower oxygen content in the exhaust system. Another commenter pointed out that elevated operating temperatures in certain engine modes can result in sulfates adding as much as 50% to total particulate mass, and asserted that ceramic traps alone were unable to offset this effect on their own.

In response to the proposed rule, MSHA received information and claims about the current efficiency of such technologies. One commenter, representing those who manufacture emissions controls, and referring to technologies other than low temperature paper filters—such as higher temperature disposable paper filters, ceramic monolith diesel particulate filters, wound ceramic fiber filters, and metal fiber filters—asserted that there were technologies which could achieve in excess of 95% filtration efficiency under ''many operating conditions.'' Another commenter submitted copies of information provided to that commenter by individual manufacturers of emission control systems, many of which made similar claims. Another commenter, however, questioned manufacturer claims, asserting big differences had been observed between such claims an independent 8-mode tests.

It appears that two groups in particular have been doing some research comparing the efficiency of recent ceramic models: the University of West Virginia, as part of that State's efforts to develop rules on the use of diesel-powered equipment underground; and VERT (Verminderung der Emissionen von Realmaschinen in Tunnelbau), a consortium of several European agencies conducting research in connection with major planned tunneling projects in Austria, Switzerland and Germany to protect occupational health and subsequent legislation in each of the three countries restricting diesel emissions in tunneling (in both cases, background on the regulatory efforts of the jurisdictions involved is discussed in section 8 of this part).

The legislature of the State of West Virginia enacted the West Virginia Diesel Act, which created the West Virginia Diesel Commission and set forth an administrative vehicle to allow and regulate the use of diesel equipment in underground coal mines in that state. West Virginia University was appropriated funds to test diesel exhaust controls, as well as an array of diesel particulate filters. The University was asked to provide technical support and data necessary for the Commission to make decisions on standards for emission controls.

The University provided data on four different engines and an assortment of configurations of available control devices, both hot gas filters and the DST® system (a system which, first cools the exhaust, then runs it through a paper filter). The range of collection efficiencies reported for the ceramic filters and oxidation catalysts combined fell between 65% and 78%. The highest collection efficiency obtained using the ISO 8 mode test cycle (test cycle described in rule) was 81% on the DST® system. The University reported problems with this system that would account for the lower than expected efficiency for a paper filter type system. A commenter who spoke for the Commission at MSHA's public hearing expressed serious reservations of the 95% collection efficiency of MSHA's proposed rule and believed it was not achievable with technology based on the University's current work. The WV Commission also provided MSHA a detailed proposal for setting a laboratory diesel particulate standard of 0.5 milligram per cubic meter. As discussed in part IV, this is similar to the Pennsylvania standard, but without a strict filter efficiency value, and as further discussed in part IV, MSHA's approach in this final rule is similar.

VERT's studies of particulate traps are detailed in two articles published in 1999 which have been widely disseminated to the diesel community here through www.DieselNet.com (Mayer et al., March 1999, and Mayer, April 1999). The March article focuses on the efficiency of the traps; the April article compares the efficiency of other approaches (OCCs, fuel reformulation, engine modifications to reduce ultra-fine particulates) with that of the traps. Here we focus only on the information about particulate traps.

The authors of the March article report that 29 particulate trap systems were tested using various ceramic, metal and fiber filter media and several regeneration systems. The authors of the March article summarize their conclusions as follows:

The results of the 4-year investigations of construction site engines on test rigs and in the field are clear: particulate trap technology is the only acceptable choice among all available measures. Traps proved to be an extremely efficient method to curtail the finest particles. Several systems demonstrated a filtration rate of more than 99% for ultra-fine particulates. Specific development may further improve the filtration rate.

A two-year field test, with subsequent trap inspection, confirmed the results pertaining to filtration characteristics of ultra-fine particles. No curtailment of the ultra-fine particles is obtained with any of the following: reformulated fuel, new lubricants, oxidation catalytic converters, and optimization of the engine combustion.

Particulate traps represent the best available technology (BAT). Traps must therefore be employed to curtail the particulate emissions that the law demands are minimized. This technology was implemented in occupational health programs in Germany, Switzerland and Austria.

On the bench tests, it appears that the traps reduce the overall particulate matter by between 70 and 80%, with better results for solid ultrafine particulates; under hot gas conditions, it appears the non-solid components of particulate matter cannot be dependably retained by these traps. Consistent with this finding, it was found that polycyclic aromatic hydrocarbons (PAHs) decreased proportionately to the gravimetric decrease of carbon mass. The tests also explored the impact of additives on trap efficiency, and the impact of back pressure.

The field tests confirmed that the traps were easy to mount and retained their reliability over time, although regeneration using an external power source was required when low exhaust temperatures failed to do this automatically. Electronic monitoring of back pressure was recommended. In general, the tests confirmed that a whole series of trap systems have a high filtration rate and stable long time properties and are capable of performing under difficult construction site conditions. Again, the field tests indicated a very high reduction (97–99%) by particulate count, but a lower rate of reduction in terms of mass.

Subsequently, VERT has evaluated additional commerically available filter systems. A list of recently evaluated hot gas filters are shown in Table II–4. The filtration efficiency, expressed on a gravimetric basis is shown in the column headed ''PMAG—without additive''. The filtration efficiencies determined by VERT for these 6 filter systems range from 80.7% to 94.5%. The average efficiency of these filters is 87%. MSHA will be updating the list of VERT's evaluated systems as they become available.

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Table II-4

Efficiency of Diesel Particulate Traps VERT-Certification Test

Average 4 operation points, ISO 8187

Trap	Date	PMAG		PZAG		ECAG	
		without Additive	with Additive	without Additive	with Additive	without Additive	with Additive
3M	VERT-Certification Test Part 1 (new)	80.7	-	98.6	99.6	-	-
Oberland		90.5	-	98.4	99.4	-	-
JMC		94.5	-	99.3	-	-	-
IBIDEN		87.2	-	99.9	-	-	-
Corning		84.9	-	99.5	99.8	-	-
HJS/CRT		83.8	-	99.4	-	98.2	-
SHW(LIB1)	After VERT Field Test Part 3 (after 2000 hrs)	3.2	22.2	96.3	97.1	-	93.1
SHW(CAT1)		77.5	87.6	97.8	98.8	97.2	96.5
BUCK(LIB2)		76.5	81.0	95.4	97.8	94.0	95.5
BUCK(CAT3)		64.2	76.2	91.0	96.8	(87.0) [2]	95.3
ECS(LIB3)		12.4	43.0	99.9	99.9	99.3	99.0
DEUTZ(LIB4) [1]		(70.5)	(76.1)	(86.6)	(91.6)	(84.2)	
UNIKAT(CAT4)		54.7	76.2	99.0	99.6	98.1	98.4
AVERAGE		66.4		98.3		97.2	

[1] Small melting damage

[2] Uncertain data

[3] Coulometry is optional for VERT certification test

PMAG: Efficiency according to Total Particulate Mass PM

PZAG: Efficiency according to Integrated Particulate Count (20 - 300 nm) PZ

ECAG: Efficiency according to Elementary Carbon EC (2 state Coulometry)

$$PMAG = \frac{PM_{before\ trap} - PM_{after\ trapF}}{PM_{before\ trapF}} = \frac{PM_{Ref} - PM_{after\ trap}}{PM_{Ref}} \quad (X\ 100\%)$$

$$PZAG = \frac{PZ_{before\ trap} - PZ_{after\ trap}}{PZ_{before\ trap}} = \frac{PZ_{Ref} - PZ_{after\ trap}}{PZ_{Ref}} \quad (X\ 100\%)$$

$$Penetration = 1 - Efficiency = = \frac{PZ_{after\ PF}}{PZ_{Ref}} \quad (X\ 100\%)$$

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Some commenters asserted that the VERT work was for relatively small engines and not for large engines, *i.e.* 600–700 hp, and hence could not be relied upon to demonstrate the availability of filters of such high efficiencies for the larger equipment used in some underground mines. MSHA believes this comment is misplaced. The efficiency of a filter is attributable to the design of the filter and not the size of the engine. VERT is documenting filter efficiencies of commercially available filters. It is customary in the industry, however, for the filter manufacturer to size the filter to fit the size of the engine. The mine operator must work with the filter manufacturer to verify that the filter needed will work for the intended machine. MSHA believes that this is no different for other types of options installed on machines for underground mining use.

More information about the results of the VERT tests on specific filters, and how MSHA intends to use this information to aid the mining industry in complying with the requirements of the standards for heavy duty equipment, generators and compressors, are discussed in Part IV of this preamble.

The accumulated dpm must be removed from particulate traps periodically. This is usually done by burning off the accumulated particulate in a controlled manner, called regeneration. If the diesel equipment on which the trap is installed has a duty cycle which creates an exhaust gas temperature greater than about 650 degrees Fahrenheit for more than 25 percent of the operating time, the unit will be self cleaning. That is, the hot exhaust gas will burn off the particulate as it accumulates. Unfortunately, only hard working equipment, such as load, haul, dump and haulage equipment usually satisfies the exhaust gas temperature and duration requirements to self regenerate.

Techniques are available to lower the temperature needed to initiate the regeneration. One technique under development is to use a fuel additive. A comparatively small amount of a chemical is added to the diesel fuel and burns along with the fuel in the combustion chamber. The additive is reported to lower the required regeneration temperature significantly. The additive combustion products are retained as a residue in the particulate trap. The trap must be removed from the equipment periodically to flush the residue. Another technique used to lower the regeneration temperature is to apply a catalyst to the surfaces of the trap material. The action of the catalyst is similar to that of the fuel additive. The catalyst also lowers the concentration of some gaseous emissions in the same manner as the oxidation catalytic converter described earlier.

A very active catalyst applied to the particulate trap surfaces and a very active catalyst in a catalytic converter installed upstream of the trap can create a situation in which the trap performs less efficiently than expected. Burning low sulfur diesel fuel, containing less than 500 ppm sulfur, will result in the creation of significant quantities of sulfates in the exhaust gas. These sulfates will still be in the gaseous state when they reach the ceramic trap and will pass through the trap. These sulfates will condense later forming diesel particulate. Special care must be taken in the selection of the catalyst formulation to ensure that sulfate formation is avoided. This problem does not occur in systems designed with a catalytic converter upstream of a water scrubber. The gaseous phase sulfates will condense when contacting the water in the scrubber and will not be discharged into the mine atmosphere. Thus far, no permissible diesel packages have been approved which incorporate a catalytic converter upstream of the water scrubber. One research project conducted by the former Bureau of Mines which attempted this arrangement was unsuccessful. In attempting to maintain a surface temperature less than the 300 degrees Fahrenheit (required for permissibility purposes) the exhaust gas was be cooled to the point that the catalytic converter did not reach the necessary operating temperature. It would appear that a means to isolate the catalytic converter from the exhaust gas water jacket is necessary for the arrangement to function as intended.

If the machine on which the particulate trap is installed does not work hard enough to regenerate the trap with the hot exhaust gas and the option to use a fuel additive or catalyzed trap is not appropriate, the trap can still be regenerated while installed on the machine. Systems are available whereby air is heated by an externally applied heat source and caused to flow through the particle trap when the engine is stopped. The heat can be supplied by an electrical resistance element installed in front of the trap. The heat can also be supplied by a burner installed into the exhaust pipe in front of the trap. The burner is fueled by an auxiliary fuel line. The fuel is ignited creating large quantities of hot gas. With both systems, an air line is also connected to the exhaust pipe to create a flow of hot gases through the particulate trap. Both systems utilize operator panels to control the regeneration process.

Equipment owners may choose to remove the particle trap from the machine to perform the regeneration. Particle traps are available with quick release devices. The trap is then placed on a specially designed device that creates a controlled flow of heated air that is passed through the filter burning off the accumulated particulate.

The selection of the most appropriate means to regenerate the trap is dependent on the equipment type, the equipment duty cycle, and the equipment utilization practices at the mine.

A program under the Canadian DEEP project is field testing dpm filter systems in a New Brunswick Mine. Investigators are testing four filter systems on trucks and scoops. The initial feedback from Canada is very favorable concerning the performance of filters. Operators are very positive and are requesting the vehicles equipped with the filters because of the noticeable improvement in air quality and an absence of smoke even under transient load conditions. One system undergoing testing utilizes an electrical heating element installed in the filter system to provide the heated air for regeneration of the filter. This heating element requires connection of the filter to an external electrical source at the end of the shift. Initial tests have been successful.

VERT has also published information on the extent of dpm filter usage in Europe as evidence that the filter technology has attained wide spread acceptance. MSHA believes this information is relevant to coal and metal/nonmetal mining because the tunneling equipment on which these filters are installed is similar to metal/nonmetal equipment and can be applied to heavy duty equipment in coal mining operations. VERT stated that over 4,500 filter systems have been deployed in England, Scandinavia, and Germany. Deutz Corporation has deployed 400 systems (Deutz's design) with full flow burners for regeneration of filters installed on engines between 50–600kw. The Oberland-Mangold company has approximately 1,000 systems in the field. They have accumulated an average of 8,400 operating hours in forklift trucks, 10,600 operating hours in construction site engines, and 19,200 operating hours in stationary equipment. The Unikat company has introduced in Switzerland over 250 traps since 1989 and 3,000 worldwide with some operating more than 20,000 hours. In German industry, approximately 1,500 traps in forklifts are installed annually.

Paper filters. In 1990, the former Bureau of Mines conducted a project to develop a means to reduce the amount of dpm emitted from permissible diesel powered equipment using technologies that were available commercially and that could be applied to existing equipment. The project was conducted with the cooperation of an equipment manufacturer, a mine operator, and MSHA. In light of the fact that all permissible diesel powered equipment, at that time, utilized water scrubbers to meet the MSHA approval requirements, the physical characteristics of the exhaust from that type of equipment were the basis for the selection of candidate technologies. The technology selected for development was the pleated media filter or paper filter as it came to be called. The filter selected was an intake air cleaner normally used for over the road trucks. That filter was acceptable for use with permissible diesel equipment because the temperature of the exhaust gas from the water scrubber was less than 170 degrees F, well below the ignition point of the filter material. Recognizing that under some operating modes, water would be discharged along with the exhaust, a water trap was installed in the exhaust stream before it passed through the filter. After MSHA conducted a thorough permissibility evaluation of the modified system, this filter was installed on a permissible diesel coal haulage vehicle and a series of in-mine trials were conducted. It was determined, by in mine ambient gravimetric sampling, that the particulate filter reduced dpm emissions by 95 percent compared with the same machine without the filter. The test results showed that the filters would last between one and two shifts, depending on how hard the equipment worked. (BOM, IC 9324).

Following the successful completion of the former Bureau of Mines mine trial, several equipment manufacturers applied for and received MSHA approval to offer the paper filter kits as options on a number of permissible diesel machines. These filter kits were installed on other machines at the mine where the original tests were conducted, and later, on machines at other mines.

Despite the initial reports on the high efficiency of paper filters, during the hearings and in the comments on this rulemaking a number of commenters questioned whether, in practice, paper filters could achieve efficiencies on the order of 95% when used on existing permissible equipment. In order to determine whether it could verify those concerns, MSHA contracted with the Southwest Research Institute to verify the ability of such a paper filter to reduce the dpm generated by a typical engine used in permissible equipment. The results of this verification investigation are reviewed in Part IV of this preamble. They confirmed that commercially available paper filters are capable of achieving very high efficiencies.

Another commenter noted that the volatile fraction of particulate is not trapped by hot gas filters, but rather passes through the filter in gaseous form. The volatile fraction consists of, among other components, gaseous forms of sulfur compounds, lube oil and the high boiling point fraction of unburned fuel. These components condense in the mine atmosphere as diesel particulate. The commenter asserted that the process of volatilization is reduced in the water cooled exhaust, but it is present nevertheless.

MSHA recognizes that the volatile fraction of dpm passes through hot gas filters. This volatile fraction later condenses in the mine atmosphere and is collected on particulate samplers. This is not the case with hot gas filters that utilize a catalytic converter. The volatile fraction is oxidized in the catalytic converter and the gases produced do not condense as particulate. Paper filters are typically used with water scrubbers or heat exchangers, both of which condense the volatile fraction into dpm before the exhaust gas reaches the paper filter. This allows the paper filter to trap the condensed volatile fraction.

Dry systems technology. The recently developed means of achieving permissibility with diesel powered equipment in the United States is the dry exhaust conditioning system or dry system. This system combines several of the concepts described above as well as new, innovative approaches. The system also solves some of the problems encountered with older technologies.

The dry system in its most basic form consists of a heat exchanger to cool the exhaust gas, a mechanical flame arrestor to prevent the discharge of any flame from within the engine into the mine atmosphere, and a spark arrestor to prevent sparks from being discharged. The surfaces of these components and the piping connecting them are maintained below the 300 degrees F required by MSHA approval requirements. A filter, of the type normally used as an intake air filter element, is installed in the exhaust system as the spark arrestor. In terms of controlling dpm emissions, the most significant feature of the system is the use of this air filter element as a particulate filter. The filter media has an allowable operating temperature rating greater than the 300 degree F exhaust gas temperature allowed by MSHA approval regulations. These filters are reported to last up to sixteen hours, depending on how hard the machine operates.

The dry system can operate on any grade without the problems encountered by water scrubbers. Furthermore, there is no problem with fog created by operation of the water scrubber. Dry systems have been installed and are operating successfully on diesel haulage equipment, longwall component carriers, longwall component extraction equipment, and in nonpermissible form, on locomotives. However, as pointed out by commenters, requiring the use of a dry system on all mining equipment would be expensive, cumbersome, and in many cases would require considerable engineering measures that might render them infeasible.

Although the dry systems were originally designed for permissible equipment applications, they can also be used directly on outby equipment (whose emissions are not already cooled), or to replace water scrubbers used to cool most permissible equipment with a system that includes additional aftertreatment.

Two manufacturers have received approval for diesel power packages that are configured as described above; Paas Technologies, (under various corporate designations including Minecraft and a registered trade name, Dry Systems Technology, or DST ®) and Jeffrey Mining Equipment Company (currently Long-Airdox-Jeffrey).

The design of the dry system manufactured by DST ® includes a catalytic converter. However, with respect to the basic Paas Technologies system, without a catalytic converter, the initial reported laboratory reductions in dpm were dramatic: up to 98%.

During the hearings, however, there were many questions about the applicability of the early results to MSHA's proposed requirement that emissions of certain equipment be reduced 95% by mass. It was indicated by a commenter that the original Paas Technology dry system tests with a paper filter were performed at West Virginia University used high sulfur fuel which is currently prohibited in underground coal mines. The commenter stated that the University tested different fuels containing varying sulfur contents and the results indicated a fluctuation in overall dpm emission results. The commenter stated the difference in dpm collection efficiency by the filter was on the order of 12 to 15%. Another commenter stated the difference in dpm reduction using a 0.37 percent fuel sulfur and a 0.04 percent fuel sulfur was about 22 percent. This commenter further stated that other published papers from Europe report the same dpm reductions with varying fuel sulfur levels, approximately 15 to 20 percent reduction.

As was stated ealier, Paas Technologies has further developed its system by the adding a catalytic converter in the exhaust before the particulate paper filter. Paas Technologies have developed a technique whereby the catalytic converter is mounted so that the exhaust gas temperature remains high enough for the converter to operate effectively while complying with the MSHA surface temperature requirement. In addition to removing most of the carbon monoxide, the catalytic converter removes most of the unburned hydrocarbons before they are cooled and condensed. This feature extends the operating life of the filter. Any sulfate formed in the catalytic converter or in the engine combustion process condenses to a solid form as the exhaust gas passes through the heat exchanger and is collected in the particulate filter.

Paas Technologies submitted a detailed set of test results on a 94hp MWM D–916–6 test engine equipped with a Model M38 DST® Management System, which included the catalytic converter, for the rulemaking record. These tests were conducted by Southwest Research Institute using an 8-mode test, with ASTM No. 2–D diesel fuel. Both the test cycle and test fuel (low sulfur) conformed with the test procedure detailed in the proposed rule and in this final rule. In idle mode, the dpm emissions were reduced about 90%; in mode 5, the dpm emissions were down 99%; on average of the 8 modes, the dpm emissions were reduced by 97%.

The Jeffrey system, which does not utilize a catalytic converter, was the subject of the MSHA verification initiative, noted in part IV. The verification was conducted in such a way as to test filter efficiency separately from whole system, with the low sulfur fuel required for coal mine use and without a catalytic converter. The verification confirmed that the paper filter has a dpm removal efficiency greater than 95 percent.

This data submitted to the rulemaking record demonstrates that paper filters used on dry systems can achieve a filtration efficiency that allows equipment to meet the 2.5 gm/hr standard with low sulfur diesel fuel both with and without a catalytic converter in the system.

Reformulated fuels. It has long been known that sulfur content can have a big effect on dpm emissions. In the diesel equipment rule, MSHA requires that fuel used in underground coal mines have less than 0.05% (500 ppm) sulfur. EPA regulations requiring that such low-sulfur fuel (less than 500 ppm) be used in highway engines, in order to limit air pollution, have in practice ensured that this is the type of diesel fuel available to mine operators, and they currently use this type of fuel for all engines.

EPA has proposed a rule which would require further reductions in the sulfur content of highway diesel fuel. Such an action was taken for gasoline fuel on December 21, 1999.

On May 13, 1999 (64 FR 26142) EPA published an Advance Notice of Proposed Rulemaking (ANPRM) relative to changes for diesel fuel. In explaining why it was initiating this action, EPA noted that diesel engines ‘‘contribute greatly’’ to a number of serious air pollution problems, and that diesel emissions account for a large portion of the country’s particulate matter and nitrogen oxides-a key precursor to ozone. EPA noted that while these emissions come mostly from heavy-duty truck and nonroad engines, they expected the contribution to dpm emissions from light-duty equipment to grow due to manufacturers’ plans to greatly increase the sale of light duty trucks. These vehicles are now subject to Tier 2 emission standards, whether powered by gasoline or diesel fuel. Such standards may be difficult to meet without advanced catalyst technologies that in turn are likely to require sulfur reductions in the fuel.

Moreover, planned Tier 3 standards for nonroad vehicles would require similar action (64 FR 26143). (For more information on the EPA planned engine standards, see section 5 of this Part). The EPA noted that the European Union has adopted new specifications for diesel fuel that would limit it to 50 ppm by 2005, (an interim limit of 350 ppm by this year), that the entire diesel fuel supply in the United Kingdom should soon be at 50 ppm, and that Japan and other nations were working toward the same goal (64 FR 26148).

In the ANPRM, EPA specifically noted that while continuously regenerating ceramic filters have shown considerable promise for limiting dpm emissions even at fairly low exhaust temperatures, the systems were fairly intolerant of fuel sulfur. Accordingly, the agency hopes to gather information on whether or not low sulfur fuel was needed for effective PM control (64 FR 26150). EPA’s proposed rule was published in May 2000 and EPA issued final regulations addressing emissions standards (December 2000) for new model year 2007 heavy-duty diesel engines and the low-sulfur fuel rule. The regulations require ultra-low sulfur fuel be phased in during 2006–2009.

A joint government-industry partnership is also investigating the relationship between varying levels of sulfur content and emissions reduction performance on various control technologies, including particulate filters and oxidation catalytic convertors. This program is supported by the Department of Energy’s Office of Heavy Vehicles Technologies, two national laboratories, the Engine Manufacturers Association, and the Manufacturers of Emission Controls Association. It is known as the Diesel Emission Control-Sulfur Effects (DECSE) Program; more information is available from its web site, http://www.ott.doe.gov/decse.

MSHA expects that once such cleaner fuel is required for transportation use, it will in practice become the fuel used in mining as well—directly reducing engine particulate emissions, increasing the efficiency of aftertreatment devices, and eventually through the introduction of new generation of cleaner equipment. Mayer states that reducing sulfur content, decreasing aromatic components and increasing the Cetane index of diesel fuel can generally result in a 5% to 15% reduction in total particulate emissions.

Several commenters in this rulemaking suggested other fuel formulations which could have a beneficial effect on dpm emissions. One commenter encouraged the use of FRF, Fire Resistant Fuel, which has various safety features as well as lower NO_X and PM, and noted it is under study for use by the military.

Another commenter noted the development of a catalytic ignition system that permits the engines to operate on alternative fuels which greatly reduce harmful emissions. For example, using a water-methanol mix, the commenter noted dramatic reductions in harmful emissions of NO_X, CO and HC over a gasoline, spark ignition engine. This commenter also noted that the ignition system could operate on a diesel engine, but provided no information about emissions reductions by its use.

Meyer reports the results of a test by VERT of a special synthetic fuel containing neither sulfur nor bound nitrogen nor aromatics, with a very high

Cetane index. The fuel performed very well, but produced only abut 10% fewer particulates than low sulfur diesel fuel, nor did it show any improvement in diminishing nonparticulate emissions.

Cabs. Even though cabs are not the type of control device that is attached to the exhaust of the diesel engine to reduce emissions, cabs can protect miners from environmental exposures to dpm. Both cabs and control booths are discussed in the context of reducing miners exposures to dpm.

A cab is an enclosure around the operator installed on a piece of mobile equipment. It can provide the same type of protection as a booth at a crusher station as found in some surface operations. While cabs are not available for all mining equipment, they are available for much of the larger equipment that also has application in the construction industry.

To be effective, a cab should be tightly sealed with windows and doors closed. Rubber seals around doors and windows should be in good condition. Door and window latches must operate properly. In addition to being well sealed, the cab should have an air filtration and pressurizing system. Air intake should be located away from engine exhaust. The airflow should provide one air change per minute for the cab and should pressurize the cab to 0.20 inches of water. While these are not absolute requirements, they do provide a guideline of how a cab should be designed. If a cab does not have an air filtration and pressurizing system, the diesel particulate concentration inside the cab will be similar to the diesel particulate concentration outside the cab.

MSHA has evaluated the efficiency of cab filters for diesel particulate reduction. Several different types of filter media have been tested in underground mines. These include standard filter paper and high efficiency filter paper. Filter papers can reduce diesel particulate exposures by 60 percent to 90 percent. When changing filter media, it is necessary to make sure that the airflow into the cab is not reduced and that the airflow through an air conditioning system is not reduced.

Although the installation of a cab does not relieve the mine operator from the responsibility of complying with the equipment dpm limits, cabs provide assistance in complying with noise and respirable dust regulations. Cabs protect the equipment operator protection from dpm, respirable dust and noise exposures.

(7) Existing Standards for Underground Coal Mines That Assist in Limiting Miner Exposure to Diesel Emissions

MSHA already has in place various requirements that indirectly help to control miner exposure to diesel emissions in underground mines—including exposure to diesel particulate. The first such requirements were developed in the 1940's; the most recent went into full effect only in November, 1999. It is important to understand these requirements because they form the base upon which this new rule is overlaid.

Early developments. In 1944, part 31 established procedures for limiting the gaseous emissions from diesel powered equipment and establishing the recommended dilution air quantity for mine locomotives that use diesel fuel. In 1949, part 32 established procedures for testing of mobile diesel-powered equipment for non-coal mines. In 1961, part 36 was added to provide requirements for the use of diesel equipment in gassy noncoal mines, in which engines must be temperature controlled to prevent explosive hazards. These rules were drafted in response to research conducted by the former Bureau of Mines.

Continued research by the former Bureau of Mines in the 1950s and 1960s led to refinements of its ventilation recommendations, particularly when multiple engines are in use. An airflow of 100 to 250 cfm/bhp for engines that have a properly adjusted fuel to air ratio was recommended (Holtz, 1960). An additive ventilation requirement was recommended for operation of multiple diesel units, which could be relaxed based on the mine operating procedures. This approach was subsequently refined to become a 100–75–50 percent guideline (MSHA Policy Memorandum 81–19MM, 1981). Under this guideline, when multiple pieces of diesel equipment are operated, the required airflow on a split of air would be the sum of: (a) 100 percent of the approval plate quantity for the vehicle with the highest approval plate air quantity requirement; (b) 75 percent of the approval plate air quantity requirement of the vehicle with the next highest approval plate air quantity requirement; and (c) 50 percent of the approval plate airflow for each additional piece of diesel equipment.

Limitations on Diesel Gasses. MSHA has limits on some of the gasses produced in diesel exhaust. These are listed in Table II–5, for both coal mines and metal/nonmetal mines, together with information about the recommendations in this regard of other organizations. As indicated in the table, MSHA requires mine operators to comply with gas specific threshold limit values (TLV®s) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1972 (for coal mines) and in 1973 (for metal and nonmetal mines).

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TABLE II-5

GASEOUS EXPOSURE LIMITS (PPM)

Pollutant	Range of Limits Recommended		MSHA Limits	
			$Coal_A$	M/NM_B
HCHO	0.016_C	0.3_D	2	2
CO	25_D	50	50	50
CO_2	$5,000_C$	5,000	5,000	5,000
NO	$25_{C,D,E}$	25	25	25
NO_2	1_F	3_D	5	5
SO_2	$2_{C,D}$	5_E	2	5

Table Notes:

A) ACGIH, 1972

B) ACGIH, 1973

C) NIOSH recommended exposure limit (REL), based on a 10-hour, time-weighted average

D) ACGIH, 1996

E) OSHA permissible exposure limit (PEL)

F) NIOSH recommends only a 1-ppm, 15-minutes, short-term exposure limit (STEL)

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To change an MSHA exposure limit, regulatory action is required because the rule does not provide for their automatic updating. In 1989, MSHA proposed changing some of these gas limits in the context of a proposed rule on air quality standards (54 FR 35760). Following opportunity for comment and hearings, a portion of that proposed air quality rule (concerning control of drill dust and blasting) was promulgated. As a result of a recent legal action, MSHA's efforts to revise the specific limits for those gases emitted by diesel engines have been placed under the continued supervision of a federal court of appeals. This action is discussed in more detail in section 9 of this Part.

Diesel Equipment Rule for Underground Coal Mines. On October 25, 1996, MSHA promulgated standards for the "Approval, Exhaust Gas Monitoring, and Safety Requirements for the Use of Diesel-Powered Equipment in Underground Coal Mines" (61 FR 55412). The history of this "diesel equipment rule" (sometimes referred to here as the "diesel safety rule" to help distinguish it from this rulemaking which is oriented toward health) is set forth as part of the history of this rulemaking (see section 9 of this part).

The diesel equipment rule focuses on the safe use of diesels in underground coal mines. Integrated requirements are established for the safe storage, handling, and transport of diesel fuel underground, training of mine personnel, minimum ventilating air quantities for diesel powered equipment, monitoring of gaseous diesel exhaust emissions, maintenance requirements, incorporation of fire suppression systems, and design features for nonpermissible machines.

Certain requirements were included in the diesel equipment rule that are directly related to reducing diesel emissions. For example, the diesel equipment rule requires that the emissions of permissible and heavy duty equipment be tested weekly. The tests are conducted using instrumentation and the tests are conducted with the engines operated at a loaded condition which is representative of actual operation. The results are monitored and recorded. Higher than normal emissions readings indicate that the engines and equipment are not being maintained in approved condition. Although some of these requirements help reduce dpm emissions, they were not included in the rule for that specific purpose.

Lower-emission engines. The diesel equipment rule requires that virtually all diesel-powered engines used in underground coal mines be approved by MSHA; see 30 CFR part 7, (approval requirements), part 36 (permissible machines defined), and part 75 (use of such equipment in underground coal mines). The approval requirements, among other things, require clean-burning engines in diesel-powered equipment (61 FR 55417). In promulgating the final rule, MSHA recognized that clean-burning engines are "critically important" to reducing toxic gasses to levels that can be controlled through ventilation. To achieve the objective of clean-burning engines, the rule sets performance standards which must be met by virtually all diesel-powered equipment in underground coal mines.

As noted in section 5 of this part, the technical requirements for approved diesel engines focus on limiting the amount of various gases that an engine can emit, including undiluted exhaust limits for carbon monoxide and oxides of nitrogen (61 FR 55419). The limits for these gasses are derived from existing 30 CFR part 36.

The diesel equipment rule also provides that the particulate matter emitted by approved engines be determined during the testing required to gain approval. The particulate index (or PI), calculated under the provisions of 30 CFR 7.89, indicates what air quantity is necessary to dilute the diesel particulate in the engine exhaust to 1 milligram of diesel particulate matter per cubic meter of air. The purpose of the PI requirement is discussed in more detail in section 5 of this part.

Gas Monitoring. The diesel equipment rule also addresses the monitoring and control of gaseous diesel exhaust emissions (30 CFR part 70; 61 FR 55413). In this regard, the rule requires that mine operators take samples of carbon monoxide and nitrogen dioxide as part of existing onshift workplace examinations (61 FR 55413, 55430–55431). Samples exceeding an action level of 50 percent of the threshold limits set forth in 30 CFR 75.322 trigger corrective action by the mine operator (30 CFR part 70, 61 FR 55413).

Engine Maintenance. The diesel equipment rule requires that diesel-powered equipment be maintained in safe and approved condition (30 CFR 75.1914; 61 FR 55414). As explained in the preamble, maintenance requirements were included because of MSHA's recognition that inadequate equipment maintenance can, among other things, result in increased levels of harmful gaseous and particulate components from diesel exhaust (61 FR 55413–55414).

The rule also requires the weekly examination of diesel-powered equipment (30 CFR 75.1914(g)). To determine if more extensive maintenance is required, the rule further requires a weekly check of the gaseous CO emission levels on permissible and heavy duty outby machines. The CO check requires that the engine be operated at a repeatable loaded condition and the CO measured. The carbon monoxide concentration in the exhaust provides a good indication of engine condition. If the CO measurement increases to a higher concentration than what was normally measured during the past weekly checks, then a maintenance person would know that a problem has developed that requires further investigation.

In addition, operators are required to establish programs to ensure that those performing maintenance on diesel equipment are qualified (61 FR 55414).

Fuel. The diesel equipment rule also requires that underground coal mine operators use diesel fuel with a sulfur content of 0.05% (500 ppm) or less (30 CFR 75.1910(a); 61 FR 55413). Some types of exhaust aftertreatment technology designed to lower hazardous diesel emissions work more effectively when the sulfur content of the fuel is low. More effective aftertreatment devices will result in reduced hydrocarbons, carbon monoxide, and particulate levels. Low sulfur fuel also greatly reduces the sulfate production from the catalytic converters currently in use in underground coal mines thereby decreasing exhaust particulate. To further reduce miners' exposure to diesel exhaust, the final rule prohibits operators from unnecessarily idling diesel-powered equipment (30 CFR 75.1916(d).

Ventilation. The diesel equipment rule requires that as part of the approval process, ventilating air quantities necessary to maintain the gaseous emissions of diesel engines within existing required ambient limits be set. The ventilating air quantities are required to appear on the engine's approval plate. The rule also requires generally that mine operators maintain the approval plate quantity minimum airflow in areas of underground coal mines where diesel-powered equipment is operated. The engine's approval plate air quantity is also used to determine the minimum air quantity in areas where multiple units of diesel powered equipment are being operated. The minimum ventilating air quantity where multiple units of diesel powered equipment are operated on working sections and in areas where mechanized mining equipment is being installed or removed, must be the sum of 100 percent of the approval plate quantities of all of the equipment. As stated in the preamble of the diesel equipment rule, MSHA believes that effective mine ventilation is a key component in the control of miners' exposure to gasses and particulate emissions generated by diesel equipment.

Impact of the diesel equipment rule on dpm. The diesel equipment rule is helping the mining community use diesel-powered equipment more safely in underground coal mines. Moreover, the diesel equipment rule has many features which reduce the emission and concentration of harmful diesel emissions in underground coal mines—including the particulate component of these emissions.

During the public hearings on the equipment rule, miners complained about the high concentrations of diesel emissions at the section loading point and in the areas of the mine where longwall equipment is being installed or removed. Accordingly, MSHA established, in that rule, provisions which would address miners' concerns.

The equipment rule required that the approval plate ventilation quantity be provided at the section loading point. The loading point is also identified as a location where regular air quality samples are required to be taken. Corrective action is required if the samples of CO and NO_2 exceeded more than one half the allowable concentration limit of these gases.

Longwall equipment installations and removals are handled in a similar manner. The diesel emissions from all of the equipment in the area of the mine where the longwall move is being made are required to be considered in establishing the amount of ventilation air to be provided. A specific location where that quantity is to be measured is established. Additionally, the same air quality sampling program required for section loading points is required for areas of the mine where the longwall move is to take place.

Permissible haulage vehicles contribute the largest quantities of emissions at the section loading point. Longwall moves are typically carried out by permissible and heavy duty equipment such as shield carriers, mules, and locomotives which produce large quantities of diesel emissions. Emissions from these vehicles are reduced by the use of approved engines, low sulfur fuel, the loaded repeatable engine condition testing, regular maintenance by trained personnel and the ventilation and sampling provisions of the diesel equipment rule.

Because the effective dates for provisions of the diesel equipment regulations are staggered, the full impact of the new rules was not known at the time the dpm hearings were held. MSHA expects that the concentrations of diesel emissions at the section loading point and during longwall moves will be reduced as these provisions are fully implemented.

In developing the diesel equipment rule, however, MSHA did not explicitly consider the risks to miners of a working lifetime of dpm exposure at very high levels, nor the actions that could be taken to specifically reduce dpm exposure levels in underground coal mines. It was understood that the agency would be taking a separate look at the health risks of dpm exposure. (61 FR 55420).

(8) Information on How Certain States Are Restricting Occupational Exposure to DPM

As noted earlier in this part, the Federal government has long been involved in efforts to restrict diesel particulate emissions into the environment—both through ambient air quality standards, and through restrictions on diesel engine emissions. While MSHA's actions to limit the concentration of dpm in underground mines are the first effort by the Federal government to deal with the special risks faced by workers exposed to diesel exhaust on the job, several states have already taken actions in this regard with respect to underground coal mines.

This section reviews some of these actions, as they were the subject of considerable discussion and comment during this rulemaking.

Pennsylvania. As indicated in section 1, Pennsylvania essentially had a ban on the use of diesel-powered equipment in underground coal mines for many years. As noted by one commenter, diesel engines were permitted provided the request was approved by the Secretary of the Department of Environmental Protection but no request was ever approved.

In 1995, one company in the State submitted a plan for approval and started negotiations with its local union representatives. This led to statewide discussions and the adoption of a new law in the State that permits the use of diesel-powered equipment in deep coal mines under certain circumstances specified in the law (Act 182). As further noted by this commenter, the drafters of the law completed their work before the issuance of MSHA's new regulation on the safe use of diesel-powered equipment in underground coal mines. The Pennsylvania law, unlike MSHA's diesel equipment rule, specifically addresses diesel particulate. The State did not set a limit on the exposure of miners to dpm, nor did it establish a limit on the concentration of dpm in deep coal mines. Rather, it approached the issue by imposing controls that will limit dpm emissions at the source.

First, all diesel engines used in underground deep coal mines in Pennsylvania must be MSHA-approved engines with an ''exhaust emissions control and conditioning system'' that meets certain tests. (Article II–A, Section 203–A, Exhaust Emission Controls). Among these are dpm emissions from each engine no greater than ''an average concentration of 0.12 mg/m^3 diluted by fifty percent of the MSHA approval plate ventilation for that diesel engine.'' In addition, any exhaust emissions control and conditioning system must include a ''Diesel Particulate Matter (DPM) filter capable of an average of ninety-five percent or greater reduction of dpm emissions.'' It also requires the use of an oxidation catalytic converter. Thus, the Pennsylvania statute requires the use of low-emitting engines, and then the use of aftertreatment devices that significantly reduce the particulates emitted from these engines.

The Pennsylvania law also has a number of other requirements for the safe use of diesel-powered equipment in the particularly hazardous environments of underground coal mines. Many of these parallel the requirements in MSHA's diesel equipment rule. Like MSHA's requirements, they too can result in reducing miner exposure to diesel particulate—*e.g.,* regular maintenance of diesel engines by qualified personnel and equipment operator examinations. The requirements in the Pennsylvania law take into account the need to maintain the aftertreatment devices required to control diesel particulate.

While both mine operators and labor supported this approach, it remains controversial. During the hearings on this rulemaking, one commenter indicated that at the time the standards were established, it would have taken a 95% filter to reduce dpm from certain equipment to the 0.12 mg/m^3 emissions standard because 0.25 sulfur fuel was being utilized. This test reported by the commenter was completed prior to MSHA promulgating the diesel equipment rule that required the use of .05% sulfur fuel. Another commenter pointed out that as operators in the state began considering the use of newer, less polluting engines, achieving an efficiency of 95% reduction of the emissions from any such engines would become even more difficult. There was some disagreement among the commenters as to whether existing technology would permit operators to meet the 0.12 mg/m^3 emission standard in many situations.

One commenter described the difficulty in efforts to get a small outby unit approved under the current Pennsylvania law. Accordingly, the industry has indicated that it would seek additional changes in the Pennsylvania diesel law. Commenters representing miners indicated that they were also involved in these discussions.

West Virginia. Until 1997, West Virginia law banned the use of diesel-powered equipment in underground coal mines. In that year, the State created the joint labor-management West Virginia Diesel Equipment Commission (Commission) and charged it with developing regulations to permit and govern diesel engine use in underground coal mines. As explained by several commenters, the Commission, in collaboration with West Virginia University (WVU), developed a protocol for testing diesel engine exhaust controls, and the legislature appropriated more than $150,000 for WVU to test diesel exhaust controls and an array of diesel particulate filters.

There were a number of comments received by MSHA on the test protocols and results. These are discussed in appropriate parts in this preamble. One commenter noted that various manufacturers of products have been very interested in how their products compare to those of other manufacturers tested by the WVU. Another asserted that mine operators had been slowing the scheduling of tests by WVA.

Pursuant to the West Virginia law establishing the Commission, the Commission was given only a limited time to determine the applicable rules for the use of diesel engines underground, or the matter was required to be referred to an arbitrator for resolution. One commenter during the hearings noted that the Commission had not been able to reach resolution and that indeed arbitration was the next step. Other commenters described the proposal of the industry members of the Commission—0.5mg/m^3 for all equipment, as configured, before approval is granted. In this regard, the industry members of the West Virginia Commission said:

> ''We urge you to accelerate the finalization of * * * these proposed rules. We believe that will aid our cause, as well as the other states that currently don't use diesel.'' (Id.)

Virginia. According to one commenter, diesel engine use in underground mining was legalized in Virginia in the mid-1980s. It was originally used on some heavy production equipment, but the haze it created was so thick it led to a drop in production. Thereafter, most diesel equipment has been used outby (805 pieces). The current state regulations consist of requiring that MSHA approved engines be used, and that the ''most up-to-date, approved, available diesel engine exhaust aftertreatment package'' be utilized. There are no distinctions between types of equipment. The commenter noted that more hearings were planned soon. Under a directive from the governor of Virginia, the state is reviewing its regulations and making recommendations for revisions to sections of its law on diesels.

Ohio. The record of this rulemaking contains little specific information on the restrictions on the underground use of diesel-powered equipment in Ohio. MSHA understands, however, that in practice it is not used. According to a communication with the Division of Mines and Reclamation of the Ohio Division of Natural Resources, this outcome stems from a law enacted on October 29, 1995, now codified as section 1567.35 of Ohio Revised Code Title 15, which imposes strict safety restrictions on the use of various fuels underground.

(9) History of this Rulemaking

As discussed throughout this part, the Federal government has worked closely with the mining community to ascertain whether and how diesel-powered equipment might be used safety and healthfully in this industry. As the evidence began to grow that exposure to diesel exhaust might be harmful to miners, particularly in underground mines, formal agency actions were initiated to investigate this possibility and to determine what, if any, actions might be appropriate. These actions, including a number of non-regulatory initiatives taken by MSHA, are summarized here in chronological sequence.

Activities Prior to Proposed Rulemaking on DPM. In 1984, the National Institute for Occupational Safety and Health (NIOSH) established a standing Mine Health Research Advisory Committee to advise it on matters involving or related to mine health research. In turn, that standing body established the Mine Health Research Advisory Committee Diesel Subgroup to determine if:

> * * * there is a scientific basis for developing a recommendation on the use of diesel equipment in underground mining operations and defining the limits of current knowledge, and recommending areas of research for NIOSH, if any, taking into account other investigators' ongoing and planned research. (49 FR 37174).

In 1985, MSHA established an Interagency Task Group with NIOSH and the former Bureau of Mines (BOM) to assess the health and safety implications of the use of diesel-powered equipment in underground coal mines.

In April 1986, in part as a result of the recommendation of the Task Group, MSHA began drafting proposed regulations on the approval and use of diesel-powered equipment in underground coal mines. Also in 1986, the Mine Health Research Advisory Committee Diesel Subgroup (which, as noted above, was created by a standing NIOSH committee) summarized the evidence available at that time as follows:

> It is our opinion that although there are some data suggesting a small excess risk of adverse health effects associated with exposure to diesel exhaust, these data are not compelling enough to exclude diesels from underground mines. In cases where diesel equipment is used in mines, controls should be employed to minimize exposure to diesel exhaust.

On October 6, 1987, pursuant to section 102(c) of the Mine Act, 30 U.S.C. 812(c), which authorizes MSHA to appoint such advisory committees as it deems appropriate, the agency appointed an advisory committee ''to provide advice on the complex issues concerning the use of diesel-powered equipment in underground coal mines.'' (52 FR 37381). MSHA appointed nine members to this committee, officially known as The Mine Safety and Health Administration Advisory Committee on Standards and Regulations for Diesel-Powered Equipment in Underground Coal Mines (hereafter the MSHA Diesel Advisory Committee). As required by section 101(a)(1) of the Mine Act, MSHA provided the MSHA Diesel Advisory Committee with draft regulations on the approval and use of diesel-powered equipment in underground coal mines. The draft regulations did not include standards setting specific limitations on diesel particulate, nor had MSHA at that time determined that such standards would be promulgated.

In July 1988, the MSHA Diesel Advisory Committee completed its work with the issuance of a report entitled ''Report of the Mine Safety and Health Administration Advisory Committee on Standards and Regulations for Diesel-Powered Equipment in Underground Coal Mines.'' It also recommended that MSHA promulgate standards governing the approval and use of diesel-powered equipment in underground coal mines. The MSHA Diesel Advisory Committee recommended that MSHA promulgate standards limiting underground coal miners' exposure to diesel exhaust.

With respect to diesel particulate, the MSHA Diesel Advisory Committee recommended that MSHA ''set in motion a mechanism whereby a diesel particulate standard can be set.'' (MSHA, 1988). In this regard, the MSHA Diesel Advisory Committee determined that because of inadequacies in the data on the health effects of diesel particulate matter and inadequacies in the technology for monitoring the amount of diesel particulate matter at that time, it could not recommend that MSHA promulgate a standard specifically limiting the level of diesel particulate matter in underground coal mines (*Id.* 64–65). Instead, the MSHA Diesel Advisory Committee recommended that MSHA ask NIOSH and the former Bureau of Mines to prioritize research in the development of sampling methods and devices for diesel particulate.

The MSHA Diesel Advisory Committee also recommended that MSHA request a study on the chronic and acute effects of diesel emissions (*Id.*). In addition, the MSHA Diesel Advisory Committee recommended that the control of diesel particulate ''be accomplished through a combination of measures including fuel requirements, equipment design, and in-mine controls such as the ventilation system and equipment maintenance in conjunction with undiluted exhaust measurements.'' The MSHA Diesel Advisory Committee further recommended that particulate emissions ''be evaluated in the equipment approval process and a particulate emission index reported.'' (*Id.* at 9).

In addition, the MSHA Diesel Advisory Committee recommended that ''the total respirable particulate, including diesel particulate, should not exceed the existing two milligrams per cubic meter respirable dust standard.'' (*Id.* at 9.) It should be noted that section 202(b)(2) of the Mine Act requires that coal mine operators maintain the average concentration of respirable dust at their mines at or below two milligrams per cubic meter which effectively prohibits diesel particulate matter in excess of two milligrams per cubic meter (30 U.S.C. 842(b)(2)).

As noted, the MSHA Diesel Advisory Committee issued its report in 1988. During that year, NIOSH issued a Current Intelligence Bulletin recommending that whole diesel exhaust be regarded as a potential carcinogen and controlled to the lowest feasible exposure level (NIOSH, 1988). In its bulletin, NIOSH concluded that although the excess risk of cancer in diesel exhaust exposed workers had not been quantitatively estimated, it is logical to assume that reductions in exposure to diesel exhaust in the workplace would reduce the excess risk. NIOSH stated that ''[g]iven what we currently know, there is an urgent need for efforts to be made to reduce occupational exposures to DEP [dpm] in mines.''

Consistent with the MSHA Diesel Advisory Committee's research recommendations, MSHA, in September 1988, formally requested NIOSH to perform a risk assessment for exposure to diesel particulate. (57 FR 500). MSHA also requested assistance from NIOSH and the former BOM in developing sampling and analytical methodologies for assessing exposure to diesel particulate in mining operations. (*Id.*). In part, as a result of the MSHA Diesel Advisory Committee's recommendation, MSHA also participated in studies on diesel particulate sampling methodologies and determination of underground occupational exposure to diesel particulate.

On October 4, 1989, MSHA published a Notice of Proposed Rulemaking on approval requirements, exposure monitoring, and safety requirements for the use of diesel-powered equipment in underground coal mines. (54 FR 40950). The proposed rule, among other things, addressed, and in fact followed, the MSHA Diesel Advisory Committee's recommendation that MSHA promulgate regulations requiring the approval of diesel engines (54 FR 40951), limiting gaseous pollutants from diesel equipment, (*Id.*), establishing ventilation requirements based on approval plate dilution air quantities (54 FR 40990), requiring equipment maintenance (54 FR 40958), requiring that trained personnel work on diesel-powered equipment, (54 FR 40995), establishing fuel requirements, (*Id.*), establishing gaseous contaminant monitoring (54 FR 40989), and requiring that a particulate index indicating the quantity of air needed to dilute particulate emissions from diesel engines be established. (54 FR 40953).

On January 6, 1992, MSHA published an Advance Notice of Proposed Rulemaking (ANPRM) indicating it was in the early stages of developing a rule specifically addressing miners exposure to diesel particulate (57 FR 500). In the ANPRM, MSHA, among other things, sought comment on specific reports on diesel particulate prepared by NIOSH and the former BOM. MSHA also sought comment on reports on diesel particulate which were prepared by or in conjunction with MSHA (57 FR 501). The ANPRM also sought comments on the health effects, technological and economic feasibility, and provisions which should be considered for inclusion in a diesel particulate rule (57 FR 501). The notice also identified five specific areas where the agency was particularly interested in comments, and about which it asked a number of detailed questions: (1) Exposure limits, including the basis thereof; (2) the validity of the NIOSH risk assessment model and the validity of various types of studies; (3) information about non-cancer risks, non-lung routes of entry, and the confounding effects of tobacco smoking; (4) the availability, accuracy and proper use of sampling and monitoring methods for diesel particulate; and (5) the technological and economic feasibility of various types of controls, including ventilation, diesel fuel, engine design, aftertreatment devices, and maintenance by mechanics with specialized training. The notice also solicited specific information from the mining community on ''the need for a medical surveillance or screening program and on the use of respiratory equipment.'' (57 FR 500). The comment period on the ANPRM closed on July 10, 1992.

While MSHA was completing a ''comprehensive analysis of the comments and any other information received'' in response to the ANPRM (57 FR 501), it took also several actions to encourage the mining community to begin to deal with the problems identified.

In 1995, MSHA sponsored three workshops ''to bring together in a forum format the U.S. organizations who have a stake in limiting the exposure of miners to diesel particulate (including) mine operators, labor unions, trade organizations, engine manufacturers, fuel producers, exhaust aftertreatment manufacturers, and academia.'' (McAteer, 1995). The sessions provided an overview of the literature and of diesel particulate exposures in the mining industry, state-of-the-art technologies available for reducing diesel particulate levels, presentations on engineering technologies toward that end, and identification of possible strategies whereby miners' exposure to diesel particulate matter can be limited both practically and effectively.

The first workshop was held in Beckley, West Virginia on September 12 and 13, and the other two were held on October 6, and October 12 and 13, 1995, in Mt Vernon, Illinois and Salt Lake City, Utah, respectively. A transcript was made. During a speech early the next year, the Deputy Assistant Secretary for MSHA characterized what took place at these workshops:

> The biggest debate at the workshops was whether or not diesel exhaust causes lung cancer and whether MSHA should move to regulate exposures. Despite this debate, what emerged at the workshops was a general recognition and agreement that a health problem seems to exist with the current high levels of diesel exhaust exposure in the mines. One could observe that while all the debate about the studies and the level of risk was going on, something else interesting was happening at the workshops: one by one miners, mining companies, and manufacturers began describing efforts already underway to reduce exposures. Many are actively trying to solve what they clearly recognize is a problem. Some mine operators had switched to low sulfur fuel that reduces particulate levels. Some had increased mine ventilation. One company had tried a soy-based fuel and found it lowered particulate levels. Several were instituting better maintenance techniques for equipment. Another had hired extra diesel mechanics. Several companies had purchased electronically controlled, cleaner, engines. Another was testing a prototype of a new filter system. Yet another was using disposable diesel exhaust filters. These were not all flawless attempts, nor were they all inexpensive. But one presenter after another described examples of serious efforts currently underway to reduce diesel emissions. (Hricko, 1996).

In March of 1997, MSHA issued, in draft form, a publication entitled ''Practical Ways to Control Exposure to Diesel Exhaust in Mining—a Toolbox''. The draft publication was disseminated by MSHA to all underground mines known to use diesel equipment and posted on MSHA's Web site.

As explained in the publication, the Toolbox was designed to disseminate to the mining community information gained through the workshops about methods being used to reduce miner exposures to dpm. MSHA's Toolbox provided specific information about nine types of controls that can reduce dpm exposures: low emission engines; fuels; aftertreatment devices; ventilation; enclosed cabs; engine maintenance; work practices and training; fleet management; and respiratory protective equipment. Some of these approaches reduce emissions from diesel engines; others focus on reducing miner exposure to whatever emissions are present. Quotations from workshop participants were used to illustrate when and how such controls might be helpful.

As it clearly stated in its introductory section entitled ''How to Use This Publication,'' the Toolbox was not designed as a guide to existing or pending regulations. As MSHA noted in that regard:

> While the (regulatory) requirements that will ultimately be implemented, and the schedule of implementation, are of course uncertain at this time, MSHA encourages the mining community not to wait to protect miners' health. MSHA is confident that whatever the final requirements may be, the mining community will find this Toolbox information of significant value.

On October 25, 1996, MSHA published a final rule addressing approval, exhaust monitoring, and safety requirements for the use of diesel-powered equipment in underground coal mines (61 FR 55412). The final rule addresses, and in large part is consistent with, the specific recommendations made by the MSHA Diesel Advisory Committee for limiting underground coal miners' exposure to diesel exhaust. As noted in section 7 of this part, the diesel safety rule was implemented in steps concluding in late 1999. Aspects of this diesel safety rule had a significant impact on this rulemaking.

In the Fall of 1997, following comment, MSHA's Toolbox was finalized and disseminated to the mining community. At the same time, MSHA made available to the mining community a software modeling tool developed by the Agency to facilitate dpm control. This model enables an operator to evaluate the effect which various alternative combinations of controls would have on the dpm concentration in a particular mine—before making the investment. MSHA refers to this model as "the Estimator". The Estimator is in the form of a template that can be used on standard computer spreadsheet programs. As information about a new combination of controls is entered, the results are promptly displayed.

Proposed Rulemaking on Dpm. On April 9, 1998, MSHA published a proposed rule to "reduce the risks to underground coal miners of serious health hazards that are associated with exposure to high concentrations of diesel particulate matter" (63 FR 17492).

MSHA went to some lengths to ensure the mining community would be able to review and comment on the proposed rule. The agency made copies of the proposal available for review by the mining community at each district and field office location, at the National Mine Safety and Health Academy, and at each technical support center. MSHA also provided the opportunity for comments to be accepted from the mining community at each of those locations, as well as through mail, e-mail and fax to the national office. MSHA also distributed the proposal to all underground mines, to mining associations and other interested parties. A copy was also posted on MSHA's website.

In order to further facilitate participation by the mining community, MSHA developed as an introduction to its preamble explaining the proposed rule a "plain language" questions and answers section.

The notice of proposed rulemaking reviewed and discussed the comments received in response to the ANPRM, including information on such control approaches as fuel type, fuel additives, and maintenance practices (63 FR 17512–17514). For the convenience of the mining community, a copy of MSHA's Toolbox was also reprinted as an Appendix at the end of the notice of proposed rulemaking (63 FR 17580 *et seq.*). A complete description of the Estimator, and several examples, were also presented in the preamble of the proposed dpm rule (63 FR 17565 *et seq.*).

The proposed dpm rule was fairly simple. In addition to miner training, the proposed rule would have required aftertreatment filters on all permissible equipment and, subsequently, on all heavy duty nonpermissible equipment. Throughout the preamble, MSHA discussed a number of other approaches that might have merit in limiting the concentration of dpm in underground coal mines. MSHA made it very clear to the mining community that the rule being proposed represented only one of the approaches which might ultimately be required by the final rule and on which comment was being solicited by the proposed rulemaking notice.

For example, the agency noted the following:

> "MSHA recognizes that a specification standard does not allow for the use of future alternative technologies that might provide the same or enhanced protection at the same or lower cost. MSHA welcomes comment as to whether and how the proposed rule can be modified to enhance its flexibility in this regard * * *. (There are) two alternative specification standards which would provide somewhat more flexibility for coal mine operators. Alternative 1 would treat the filter and engine as a package that has to meet a particular emission standard. Instead of requiring that all engines be equipped with a high-efficiency filter, this approach would provide some credit for the use of lower-polluting engines. Alternative 2 would also provide credit for mine ventilation beyond that required." (63 FR 17498)

These alternatives were further discussed in a separate Question and Answer (#12). The agency was also clear it would welcome comment on "whether there are some types of light-duty equipment whose dpm emissions should, and could feasibly, be controlled", and "whether it would be feasible for this sector to implement a requirement that any new light-duty equipment added to a mine's fleet be filtered" Question and Answer (#6) (63 FR 17556).

MSHA also discussed and welcomed comment on a number of other alternatives: *e.g.,* restricting the exposure of underground coal mines to all fine particulates regardless of source (63 FR 17495); and the use of administrative controls (*e.g.,* rotation of personnel) and personal protective equipment (*e.g.,* respirators) to reduce the dpm exposure of miners. The Agency also sought comments on its risk assessment, presented in full in the preamble to the proposed rule (Part III). As noted therein, this was the first risk assessment ever performed by the agency to be peer reviewed. Such a review is not required under the agency's statute, but MSHA took the time to obtain such a review in this instance due to significant disagreement within the mining community about the health risks of exposure to dpm (63 FR 17521).

MSHA also asked for comment on its economic assumptions in the preamble. Two of the Questions and Answers (#5 and #7) were specifically devoted to cost impacts, including those on small mines. MSHA also specifically requested all members of the mining community to consider using the Estimator in developing comments on the proposed rulemaking (63 FR 17565).

On July 14, 1998, in accordance with the National Environmental Protection Act, MSHA published a notice in the **Federal Register** seeking comment on its preliminary determination that the proposed rule would not have a significant environmental impact (63 FR 37796).

The initial comment period was scheduled to last for 120 days until August 7, 1998. In response to requests from the public, on August 5, 1998, MSHA extended the initial comment period on the proposed rule (and the comment period on its preliminary determination of no significant environmental impact) for an additional 60 days, until October 9, 1998 (63 FR 41755). That notice also announced MSHA's intent to hold public hearings on the proposal.

On October 19, 1998, MSHA announced in the **Federal Register** locations of four public hearings on the proposed rule. The agency further announced that the close of the post-hearing comment period and rulemaking record would be on February 16, 1999 (63 FR 55811).

In November 1998, MSHA held hearings in Salt Lake City, Utah and Beckley, West Virginia. In December 1998, hearings were held in Mt. Vernon, Illinois, and Birmingham, Alabama.

These hearings were well attended. Testimony was presented by individual miners, representatives of miners, individual coal companies, mining industry associations, representatives of engine and equipment manufacturers and one individual manufacturer. Members of the mining community participating had an extensive opportunity to hear and respond to alternative views; some participated in several hearings. They also had an opportunity to engage in direct dialogue with members of MSHA's rulemaking committee-responding to questions and asking questions on their own. There was extensive comment not only about the provisions of the proposed rule itself, but also about the need for diesel powered equipment in this sector, the risks associated with its use, the need for regulation in this sector, alternative approaches (including but not limited to those on which MSHA specifically sought comment), and the technological and economic feasibility of various alternatives.

During the hearings, MSHA made a number of requests that information provided at the hearing be supplemented by submission of cited sources, additional data, and in particular for data to support assertions made about various control technologies. MSHA again solicited information concerning the agency's cost assumptions, for the results of studies using MSHA's Estimator model, and also asked for any data on a number of other points. For example, the agency requested further information on the size distribution of particles from cleaner engines, on the viability of a fine particulate standard in lieu of a dpm standard, for a list of any studies concerning the risks of dpm or lack thereof, and data on equipment upgrades.

On February 12, 1999, (64 FR 7144) MSHA published a notice in the **Federal Register** announcing: (1) The availability of three additional studies discussed in the preamble of the proposed rule but not available at the time of publication; and (2) the extension of the post-hearing comment period and close of record for 60 additional days, until April 30, 1999.

On April 27, 1999, in response to requests from the public, MSHA extended the post-hearing comment period and close of record for 90 additional days, until July 26, 1999 (64 FR 22592).

On July 8, 1999, MSHA published a notice in the **Federal Register** correcting technical errors in the preamble discussion on the Diesel Emission Control Estimator formula in the Appendix to Part V of the proposed rulemaking notice, and correcting Figure V–5 of the preamble. Comments on these changes were solicited by July 26, 1999, the close of the rulemaking record (64 FR 36826). The Estimator model was subsequently published in the literature.

The rulemaking record closed on July 26, 1999, fifteen months after the date the proposed rule was published for public notice. The comments, like the hearings, reflected extensive participation in this effort by the full range of interests in the mining community and covered a full range of ideas and alternatives.

On June 30, 2000, the rulemaking record was reopened for 30 days in order to obtain public comment on certain additional documents which the agency determined should be placed in the rulemaking record. Those documents were MSHA's paper filter verification studies and the recent information from VERT on the performance of hot gas filters mentioned in section 6 of this Part. In addition, the notice provided an opportunity for comment on additional documents being placed in the rulemaking record for a related rulemaking for underground metal and nonmetal mines, and an opportunity to comment on some additional documents on risk being placed in both records. In this regard, the notice reassured the mining community that any comments filed on risk in either rulemaking proceeding would be placed in both records, since the two rulemakings utilize the same risk assessment.

Other Related Activity. On September 3, 1999, the United States Court of Appeals for the District of Columbia Circuit issued its decision on writ of mandamus sought by the United Mine Workers to compel MSHA to issue final regulations controlling gaseous emissions in the exhaust of diesel engines used in underground coal mines. (190 F.3d 545.) The UMWA argued that such action should have been completed some years before as part of MSHA's air quality rulemaking to update emissions limits on hundreds of exposure limits. The Court found that the Agency was in violation of the statute's requirement that the Secretary must either promulgate final regulations, or explain her decision not to promulgate them, within ninety days of the certification of the record of a hearing if one is held or the close of the public comment period if a hearing is not held 30 U.S.C. 811(a)(4). However, the Court declined to immediately issue the mandamus order sought in this case because, among other factors: (a) The UMWA agreed that the diesel equipment rules alone may have the desired effect of reducing exposure to these gases; (b) the UMWA further agreed that the control of diesel particulate matter and respirable mine dust rank as higher rulemaking priorities for MSHA; and (c) MSHA submitted a tentative schedule for such rulemaking that the court found to be reasonable. However, the court retained jurisdiction of the case to ensure MSHA would move forward on this matter, and ordered several reports by the agency on its progress on December 31, 1999, June 30, 2000, December 31, 2000, and December 31, 2001.

III. Risk Assessment

Introduction

MSHA has reviewed the scientific literature to evaluate the potential health effects of occupational dpm exposures at levels encountered in the mining industry. This part of the preamble presents MSHA's review of the currently available information and MSHA's assessment of health risks associated with those exposures. All material submitted during the public comment periods was considered before MSHA drew its final conclusions.

The risk assessment begins in Section III.1, with a discussion of dpm exposure levels observed by MSHA in the mining industry. This is followed by a review, in Section III.2, of information available to MSHA on health effects that have been studied in association with dpm exposure. Finally, in Section III.3 entitled ''Characterization of Risk,'' the Agency considers three questions that must be addressed for rulemaking under the Mine Act and relates the available information about risks of dpm exposure at current levels to the regulatory requirements.

A risk assessment must be technical enough to present the evidence and describe the main controversies surrounding it. At the same time, an overly technical presentation could cause stakeholders to lose sight of the main points. MSHA is guided by the first principle the National Research Council established for risk characterization, that the approach be:

[a] decision driven activity, directed toward informing choices and solving problems * * * Oversimplifying the science or skewing the results through selectivity can lead to the inappropriate use of scientific information in risk management decisions, but providing full information, if it does not address key concerns of the intended audience, can undermine that audience's trust in the risk analysis.

Although the final rule covers only one sector, this portion of the preamble was intended to enable MSHA and other interested parties to assess risks throughout the coal and M/NM mining industries. Accordingly, the risk assessment includes information pertaining to all sectors of the mining industry. All public comments on the exposures of miners and the health effects of dpm exposure—whether submitted specifically for the coal rulemaking or for the metal/nonmetal rulemaking—were incorporated into the record for each rulemaking and have been considered for this assessment.

MSHA had an earlier version of this risk assessment independently peer reviewed. The risk assessment as proposed incorporated revisions made in accordance with the reviewers' recommendations, and the final version presented here contains clarifications and other responses to public comments. With regard to the risk assessment as published in the proposed preamble, the reviewers stated that:

* * * principles for identifying evidence and characterizing risk are thoughtfully set out. The scope of the document is carefully described, addressing potential concerns about the scope of coverage. Reference citations are adequate and up to date. The document is written in a balanced fashion, addressing uncertainties and asking for additional information and comments as appropriate. (Samet and Burke, Nov. 1997).

Some commenters generally agreed with this opinion. Dr. James Weeks, representing the UMWA, found the proposed risk assessment to be ''balanced, thorough, and systematic.'' Dr. Paul Schulte, representing NIOSH, stated that ''MSHA has prepared a thorough review of the health effects associated with exposure to high concentrations of dpm, and NIOSH concurs with the published [proposed] characterization of risks associated with these exposures.'' Dr. Michael Silverstein, representing the Washington State Dept. of Labor and Industries, found MSHA's ''regulatory logic * * * thoroughly persuasive.'' He commented that ''the best available scientific evidence shows that diesel particulate exposure is associated with serious material impairment of health * * * the evidence * * * is particularly strong and certainly provides a sufficient basis for regulatory action.''

Many commenters, however, vigorously criticized various aspects of the proposed assessment and some of the scientific studies on which it was based. MSHA's final assessment, published here, was modified to respond to all of these criticisms. Also, in response to commenters' suggestions, this assessment incorporates some research studies and literature reviews not covered or inadequately discussed in the previous version.

Some commenters expressed the opinion that the proposed risk assessment should have been peer-reviewed by a group representing government, labor, industry, and independent scientists. Since the rulemaking process included a pre-hearing comment period, eight public hearings (four for coal and four for M/NM), and two post-hearing comment periods, these constituencies had ample opportunity to review and comment upon MSHA's proposed risk assessment. The length of the comment period for the Coal Dpm proposal was 15 months. The length of the comment period for the Metal/Nonmetal Dpm proposal was nine months.

1. Exposures of U.S. Miners

Information about U.S. miner exposures comes from published studies and from additional mine investigations conducted by MSHA since 1993.[3] Previously published studies of exposures to dpm among U.S. miners are: Watts (1989, 1992), Cantrell (1992, 1993), Haney (1992), and Tomb and Haney (1995). MSHA has also conducted investigations subsequent to the period covered in Tomb and Haney (1995), and the previously unpublished data through mid-1998 are included here. Both the published and unpublished studies were placed in the record with the proposal, giving MSHA's stakeholders the opportunity to analyze and comment on all of the exposure data considered.

MSHA's field studies involved measuring dpm concentrations at a total of 50 mines: 27 underground metal and nonmetal (M/NM) mines, 12 underground coal mines, and 11 surface mining operations (both coal and M/NM). At all surface mines and all underground coal mines, dpm measurements were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor. With few exceptions, dpm measurements at underground M/NM mines were made using the Respirable Combustible Dust (RCD) method (with

[3] MSHA has only limited information about miner exposures in other countries. Based on 223 personal and area samples, average exposures at 21 Canadian noncoal mines were reported to range from 170 to 1300 μg/m^3 (respirable combustible dust), with maximum measurements ranging from 1020 to 3100 μg/m^3 (Gangel and Dainty, 1993). Among 622 full shift measurements collected since 1989 in German underground noncoal mines, 91 (15%) exceeded 400 μg/m^3 (total carbon) (Dahmann et al., 1996). As explained elsewhere in this preamble, 400 μg/m^3 (total carbon) corresponds to approximately 500 μg/m^3 dpm.

no impactor). At two of the underground M/NM mines, measurements were made using the total carbon (TC) method, and at one, RCD measurements were made in one year and TC measurements in another. Measurements at the two remaining underground M/NM mines were made using the size-selective method, as in coal and surface mines.[4] Weighing errors inherent in the gravimetric analysis required for both size-selective and RCD methods become statistically insignificant at the relatively high dpm concentrations observed.

According to MSHA's experience, the dpm samples reflect exposures typical of mines known to use diesel equipment for face haulage in the U.S. However, they do not constitute a random sample of mines, and care was taken in the proposed risk assessment not to characterize results as necessarily representing conditions in all mines. Several commenters objected to MSHA's use of these exposure measurements in making comparisons to exposures reported in other industries and, for M/NM, in estimating the proposed rule's impact. These objections are addressed in Sections III.1.d and III.3.b.ii(3)(c) below. Comments related to the measurement methods used in underground coal and M/NM mines are addressed, respectively, in Sections III.1.b and III.1.c.

Each underground study typically included personal dpm exposure measurements for approximately five production workers. Also, area samples were collected in return airways of underground mines to determine diesel particulate emission rates.[5] Operational information such as the amount and type of equipment, airflow rates, fuel, and maintenance was also recorded. Mines were selected to obtain a wide range of diesel equipment usage and mining methods. Mines with greater than 175 horsepower and less than 175 horsepower production equipment were sampled. Single and multiple level mines were sampled. Mine level heights ranged from eight to one-hundred feet. In general, MSHA's studies focused on face production areas of mines, where the highest concentrations of dpm could be expected; but, since some miners do not spend their time in face areas, samples were collected in other areas as well, to get a more complete picture of miner exposure. Because of potential interferences from tobacco smoke in underground M/NM mines, samples were not collected on or near smokers.

Table III–1 summarizes key results from MSHA's studies. The higher concentrations in underground mines were typically found in the haulageways and face areas where numerous pieces of equipment were operating, or where airflow was low relative to the amount of equipment operating. In production areas and haulageways of underground mines where diesel powered equipment was used, the mean dpm concentration observed was 644 $\mu g/m^3$ for coal and 808 $\mu g/m^3$ for M/NM. In travelways of underground mines where diesel powered equipment was used, the mean dpm concentration (based on 112 area samples not included in Table III–1) was 517 $\mu g/m^3$ for M/NM and 103 $\mu g/m^3$ for coal. In surface mines, the higher concentrations were generally associated with truck drivers and front-end loader operators. The mean dpm concentration observed was less than 200 $\mu g/m^3$ at all eleven of the surface mines in which measurements were made. More information about the dpm concentrations observed in each sector is presented in the material that follows.

TABLE III–1.—FULL-SHIFT DIESEL PARTICULATE MATTER CONCENTRATIONS OBSERVED IN PRODUCTION AREAS AND HAULAGEWAYS OF 50 DIESELIZED U.S. MINES

Mine type	Number of mines	Number of samples	Mean exposure ($\mu g/m^3$)	Standard error of mean ($\mu g/m^3$)	Exposure range ($\mu g/m^3$)
Surface	11	45	88	11	9–380
Underground Coal[a]	12	226	644	41	0–3.650
Underground Metal and Nonmetal	27	355	808	39	10–5.570

Note: Intake and return area samples are excluded.

a. Underground Coal Mines

Approximately 145 out of the 910 existing underground coal mines currently utilize diesel powered equipment. Of these 145 mines, 32 mines currently use diesel equipment for face coal haulage. The remaining mines use diesel equipment for transportation, materials handling and other support operations. MSHA focused its efforts in measuring dpm concentrations in coal mines on mines that use diesel powered equipment for face coal haulage. Twelve mines using diesel-powered face haulage were sampled. Mines with diesel powered face haulage were selected because the face is an area with a high concentration of vehicles operating at a heavy duty cycle at the furthest end of the mine's ventilation system.

Diesel particulate levels in underground mines depend on: (1) The amount, size, and workload of diesel equipment; (2) the rate of ventilation; and, (3) the effectiveness of whatever diesel particulate control technology may be in place. In the dieselized mines studied by MSHA, the sections used either two or three diesel coal haulage vehicles. In eastern mines, the haulage vehicles were equipped with a nominal 100 horsepower engine. In western mines, the haulage vehicles were equipped with a nominal 150 horsepower engine. Ventilation rates ranged from the approval plate requirement, based on the 100–75–50 percent rule (Holtz, 1960), to ten times the approval plate requirement. In most cases, the section airflow was approximately twice the approval plate requirement. Other control technology included aftertreatment filters and fuel. Two types of aftertreatment filters were used. These filters included a disposable diesel emission filter (DDEF) and a Wire Mesh Filter (WMF). The DDEF is a commercially available product; the WMF was developed by and only used at one mine. Both low sulfur and high sulfur fuels were used.

Figure III–1 displays the range of exposure measurements obtained by MSHA in the field studies it conducted in underground coal mines. A study

[4] The various methods of measuring dpm are explained in section 3 of Part II of the preamble to the proposed rule. This explanation, along with additional information on these methods, is also provided in section 3 of Part II of the preamble to the final M/NM rule.

[5] Since area samples in return airways do not necessarily represent locations where miners normally work or travel, they were excluded from the present analysis. A number of area samples were included, however, as described in Sections III.1.b and III.1.c. The included area samples were all taken in production areas and haulageways.

normally consisted of collecting samples on the continuous miner operator and coal haulage vehicle operators for two to three shifts, along with area samples in the haulageways. A total of 142 personal samples and 84 area samples were collected, excluding any area samples taken in intake or return airways.

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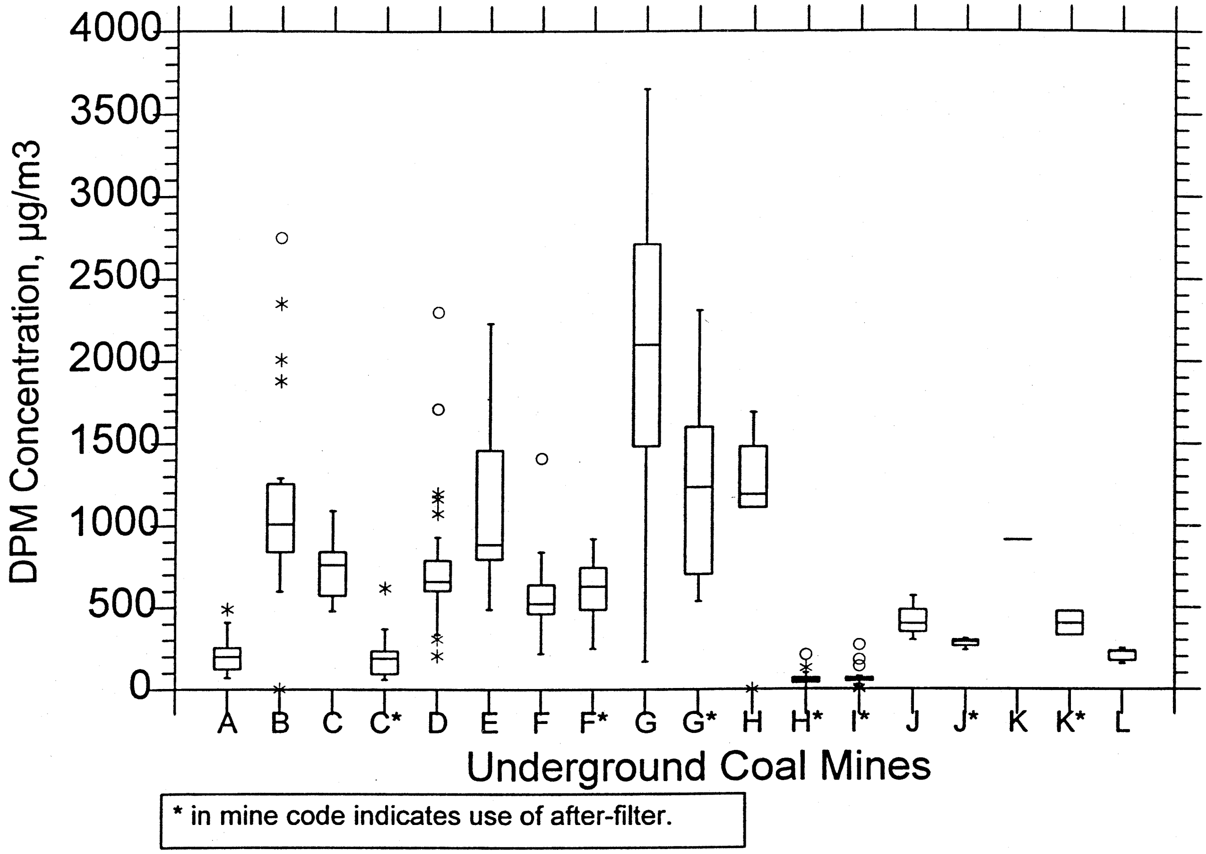

Figure 5 Box plots (Tukey, 1977) for dpm concentrations observed at 12 underground coal mines. Top and bottom of each box represent upper and lower quartiles, respectively. "Belt" inside box represents median. Vertical lines span nearly all measurements. Isolated points (either ✳ or ○) are outliers, representing unusually high or low measurements compared to other observations at the same mine. All dpm measurements were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor.

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As stated in the proposed risk assessment, no statistically significant difference was observed in mean dpm concentration between the personal and area samples.[6] A total of 19 individual measurements exceeded 1500 µg/m³, still excluding intake and return area samples. Although the three highest of these were from area samples, nine of the 19 measurements exceeding 1500 µg/m³ were from personal samples.

In six mines, measurements were taken both with and without use of disposable after-treatment filters, so that a total of eighteen studies, carried out in twelve mines, are displayed. Without use of after-treatment filters, average observed dpm concentrations exceeded 500 µg/m³ in eight of the twelve mines and exceeded 1000 µg/m³ in four.[7] At five of the twelve mines, all dpm measurements were 300 µg/m³ or greater in the absence of after-treatment filters.

The highest dpm concentrations observed at coal mines were collected at Mine "G." Eight of these samples were collected during employment of WMFs, and eight were collected while filters were not being employed. Without filters, the mean dpm concentration observed at Mine "G" was 2052 µg/m³ (median = 2100 µg/m³). With

[6] One commenter (IMC Global) noted that MSHA had provided no data verifying this statement. For the 142 personal samples, the mean dpm concentration measurement was 608 µg/m³, with a standard error of 42.5 µg/m³. For the 84 area samples, the mean was 705 µg/m³, with a standard error of 82.1 µg/m³. The significance level (p-value) of a t-test comparing these means is 0.29 using a separate-variance test or 0.25 using a pooled-variance test. Therefore, a difference in population means cannot be inferred at any confidence level greater than 75%. Here, and in other sections of this risk assessment, MSHA has employed standard statistical methods described in textbooks on elementary statistical inference.

[7] In coal mine E, the average as expressed by the mean exceeded 1000 µg/m³, but the median did not.

employment of WMFs, the mean dropped to 1241 µg/m^3 (median = 1235 µg/m^3).

Filters were employed during three of the four studies showing median dpm concentration at or below 200 µg/m^3. After adjusting for outby sources of dpm, exposures were found to be reduced by up to 95 percent in mines using the DDEF and by approximately 50 percent in the mine using the WMF.

The higher dpm concentrations observed at the mine using the WMF (Mine ''G*'') are attributable partly to the lower section airflow. The only study without filters showing a median concentration at or below 200 µg/m^3 was conducted in a mine (Mine ''A'') which had section airflow approximately ten times the nameplate requirement. The section airflow at the mine using the WMF was approximately the nameplate requirement.

Some commenters [*e.g.,* WV Coal Assoc and Energy West] objected to MSHA's presentation of underground coal mine exposures based on measurements made using the size-selective method (gravimetric determination of the amount of submicrometer dust collected with an impactor). These commenters argued that the data were '' * * * collected with emissions monitoring devices discredited by MSHA itself in the preamble * * *'' and that these measurements do not reliably ''* * * distinguish it [dpm] from other particles in coal mine dust, at the critical upper end range of submicron particles.''

MSHA did not ''discredit'' use of the size-selective method for all purposes. As discussed elsewhere in this preamble, the size-selective method of measuring dpm was designed by the former BOM specifically for use in coal mines, and the size distribution of coal mine dust was taken into account in its development. Despite the recognized interference from a small fraction of coal mine dust particles, MSHA considers gravimetric size-selective measurements to be reasonably accurate in measuring dpm concentrations greater than 200 µg/m^3, based on a full-shift sample, when coal mine dust concentrations are not excessive (*i.e.,* not greater than 2.0 mg/m^3). Interference from submicrometer coal mine dust is counter-balanced, to some extent, by the fraction of larger size, uncaptured dpm. Coal mine dust concentrations were not excessive when MSHA collected its size-selective samples. Therefore, even if as much as 10 percent of the coal mine dust were submicrometer, this fraction would not have contributed significantly to the high concentrations observed at the sampled mines.

At lower concentrations, or shorter sampling times, random variability in the gravimetric determination of weight gain becomes significant, compared to the weight of dust accumulated on the filter. For this reason, MSHA has rejected the use of the gravimetric size-selective method for enforcement purposes.[8] This does not mean, however, that MSHA has ''discredited'' this method for other purposes, including detection of very high dpm concentrations at coal mines (i.e., greater than 500 µg/m^3) and estimation of average dpm concentrations, based on multiple samples, when coal mine dust concentrations are not excessive. On the contrary, MSHA regards the gravimetric size-selective method as a useful tool for detecting and monitoring very high dpm concentrations and for estimating average exposures.

[8] MSHA has concluded that random weighing variability would make it impractical to use the size-selective method to enforce compliance with any dpm concentration limit less than about 300 µg/m^3. MSHA believes that, at such levels, single-sample noncompliance determinations based on the size-selective method could not be made at a sufficiently high confidence level.

b. Underground Metal and Nonmetal Mines

Currently there are approximately 265 underground M/NM mines in the United States. Nearly all of these mines utilize diesel powered equipment, and 27 of those doing so were sampled by MSHA for dpm.[9] The M/NM studies typically included measurements of dpm exposure for dieselized production equipment operators (such as truck drivers, roof bolters, haulage vehicles) on two to three shifts. A number of area samples were also collected. None of the M/NM mines studied were using diesel particulate afterfilters.

Figure III–2 displays the range of dpm concentrations measured by MSHA in the 27 underground M/NM mines studied. A total of 275 personal samples and 80 area samples were collected, excluding intake and return area samples. Personal exposures observed ranged from less than 100 µg/m^3 to more than 3500 µg/m^3. Exposure measurements based on area samples ranged from less than 100 µg/m^3 to more than 3000 µg/m^3. With the exception of Mine ''V'', personal exposures were for face workers. Mine ''V'' did not use dieselized face equipment.

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[9] The proposal discussed data from 25 underground M/NM mines. Studies at two additional mines, carried out too late to be included in the proposal, were placed into the public record along with the earlier studies. During the proceedings, MSHA provided copies of all of these studies to stakeholders requesting them.

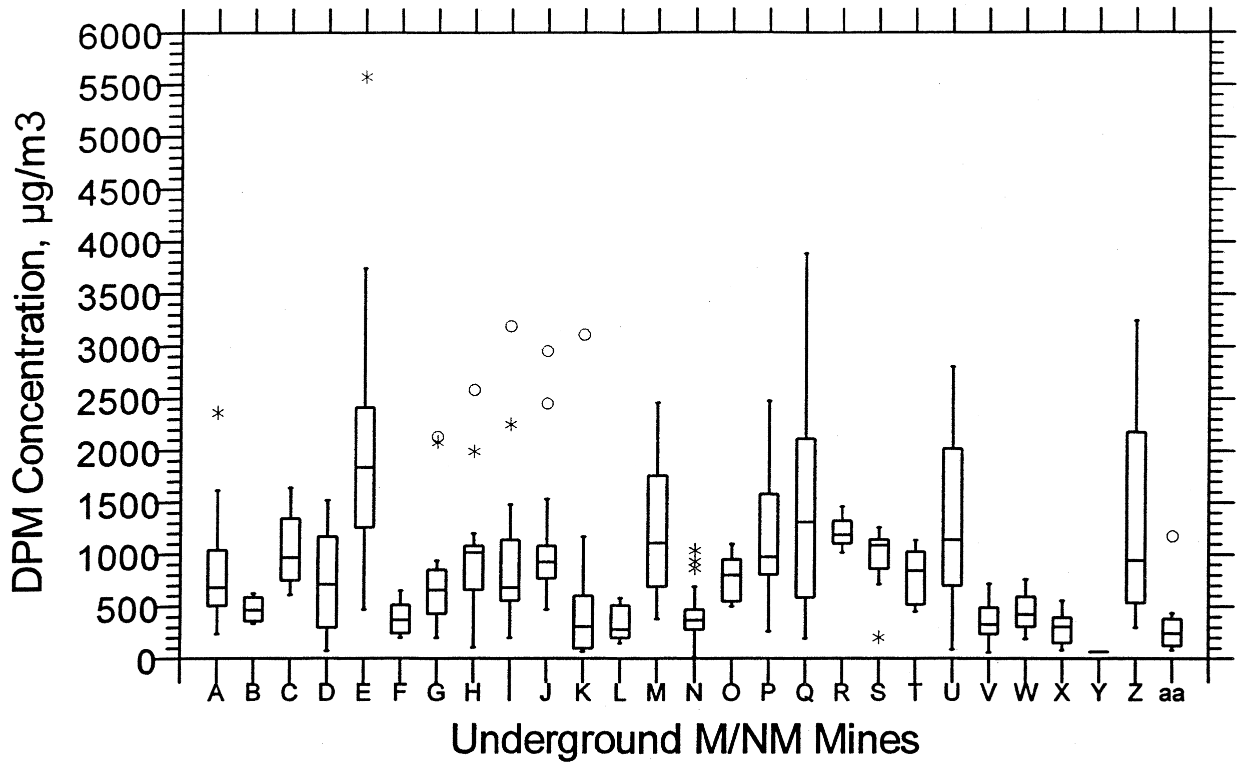

Figure 6 Box plots (Tukey, 1977) for dpm concentrations observed at 27 underground metal and nonmetal mines. Top and bottom of each box represent upper and lower quartiles, respectively. "Belt" inside box represents median. Vertical lines span nearly all measurements. Isolated points (either ✳ or ○) are outliers, representing unusually high or low measurements compared to other observations at same mine. Measurements at Mine "T" and on one visit to mine "D" were made using the size-selective method, based on gravimetric determinationof the amount of submicrometer dust collected with an impactor. Measurements on another visit to mine "D" and at Mines "Z" and "aa" were made using TC method. All other measurements were made using RCD method. Because of potential interferences from cigarette smoke, samples were not collected on or near smokers.

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As stated in the proposed risk assessment, no statistically significant difference was observed in mean dpm concentration between the personal and area samples.[10] A total of 45 individual measurements exceeded 1500 μg/m³, still excluding intake and return area samples. The three highest of these, all exceeding 3500 μg/m³, were from personal samples. Of the 45 measurements exceeding 1500 μg/m³, 30 were from personal samples and 15 were from area samples.

Average observed dpm concentrations exceeded 500 μg/m³ in 18 of the 27 underground M/NM mines and exceeded 1000 μg/m³ in 12.[11] At eight of the 27 mines, all dpm measurements exceeded 300 μg/m³. The highest dpm concentrations observed at M/NM mines were collected at Mine ''E''. Based on 16 samples, the mean dpm concentration observed at Mine ''E'' was 2008 μg/m³ (median = 1835 μg/m³). Twenty-five percent of the dpm measurements at this mine exceeded 2400 μg/m³. All four of these were based on personal samples.

As with underground coal mines, dpm levels in underground M/NM mines are related to the amount and size of equipment, to the ventilation rate, and to the effectiveness of the diesel particulate control technology employed. In the dieselized M/NM mines studied by MSHA, front-end-loaders were used either to load ore onto trucks or to haul and load ore onto belts. Additional pieces of diesel powered support equipment, such as bolters and mantrips, were also used at the mines. The typical piece of production equipment was rated at 150 to 350 horsepower. Ventilation rates in the M/NM mines studied mostly ranged from 100 to 200 cfm per horsepower of equipment. In only a few of the mines inventoried did ventilation exceed 200 cfm/hp. For single-level mines, working areas were ventilated in series (*i.e.*, the exhaust air from one area became the intake for the next working area). For multi-level mines, each level typically had a separate fresh air supply. One or two working areas could be on a level. Control technology used to reduce diesel particulate emissions in mines inventoried included oxidation catalytic converters and engine maintenance programs. Both low sulfur and high sulfur fuel were used; some mines used aviation grade low sulfur fuel.

Some commenters argued that, because of the limited number of underground M/NM mines sampled by MSHA, ''* * * results of MSHA's admittedly non-random sample cannot be extrapolated to other mines.'' [MARG] More specifically, IMC Global claimed that since only 25 [now 27] of about 260 underground M/NM mines were sampled,[12] then ''if the * * * measurements are correct, this information shows at best potential exposure problems to diesel particulate in only 10% of the miners working in the metal-nonmetal mining sector and then only for certain unlisted commodities.'' [13] IMC Global went on to suggest that MSHA should ''perform sufficient additional exposure monitoring * * * to show that the diesel particulate exposures are representative of the entire industry before promulgating regulations that will be applicable to the entire industry.''

As mentioned earlier, MSHA acknowledges that the mines for which dpm measurements are available do not comprise a statistically random sample of all underground M/NM mines. MSHA also acknowledges that the results obtained for these mines cannot be extrapolated in a statistically rigorous way to the entire population of underground M/NM mines. According to MSHA's experience, however, the selected mines (and sampling locations within those mines) represent typical diesel equipment use conditions at underground M/NM mines. MSHA believes that results at these mines, as depicted in Figure III–2, in fact fairly reflect the variety of diesel equipment used by the industry, regardless of type of M/NM mine. Based on its extensive experience with underground mines, MSHA believes that this body of data better represents those diverse diesel equipment use conditions, with respect to dpm exposures, than any other body of data currently available.

MSHA strongly disagrees with IMC Global's contention that, ''* * * this information shows at best potential exposure problems to diesel particulate in only 10% of the miners working in the metal-nonmetal mining sector.'' IMC Global apparently drew this conclusion from the fact that MSHA sampled approximately ten percent of all underground M/NM mines. This line of argument, however, depends on an unwarranted and highly unrealistic assumption: Namely, that all of the underground M/NM mines not included in the sampled group of 25 experience essentially no ''potential [dpm] exposure problems.'' MSHA certainly did not go out and, by chance or design, pick for sampling just exactly those mines experiencing the highest dpm concentrations. IMC Global's argument fails to recognize that the sampled mines could be fairly representative without being randomly chosen.

MSHA also disagrees with the premise that 27 [or 25 as in the proposal] is an inherently insufficient number of mines to sample for the purpose of identifying an industry-wide dpm exposure problem that would justify regulation. The between-mine standard deviation of the 27 mean concentrations observed within mines was 450 μg/m³. Therefore, the standard error of the estimated grand mean, based on the variability observed between mines, was

$$450/\sqrt{27} = 87\ \mu g/m^3.$$ [14]

MSHA considers this degree of uncertainty to be acceptable, given that the overall mean concentration observed exceeded 800 μg/m³.

Several commenters questioned MSHA's use of the RCD and size-selective methods for measuring dpm exposures at underground M/NM mines. IMC Global indicated that MSHA's RCD measurements might systematically inflate the dpm concentrations presented in this section, because ''* * * estimates for the non-diesel particulate component of RCD actually vary between 10% to 50%, *averaging 33%*.''

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[10] One commenter (IMC Global) noted that MSHA had provided no data verifying this statement. For the 275 personal samples, the mean dpm concentration measurement was 770 μg/m³, with a standard error of 42.8 μg/m³. For the 80 area samples, the mean was 939 μg/m³, with a standard error of 86.6 μg/m³. The significance level (p-value) of a t-test comparing these means is 0.08 using a separate-variance test or 0.07 using a pooled-variance test. Therefore, a difference in population means cannot be inferred at a 95% confidence level.

[11] At M/NM mines C, I, J, P, and Z the average as expressed by the mean exceeded 1000 μg/m³ but the median did not. At M/NM mines H and S, the median exceeded 1000 μg/m³ but the mean did not. At M/NM mine K, the mean exceeded 500 μg/m³, but the median did not.

[12] Three underground M/NM mine surveys, carried out too late to be included in the discussion, were placed into the public record and provided to interested stakeholders. These surveys contained data from two additional underground M/NM mines (''Z'' and ''aa'') and additional data for a mine (''d'') that had previously been surveyed. The risk assessment has now been updated to include these data, representing a total of 27 underground M/NM mines.

[13] A breakdown by commodity is given at the end of this subsection.

[14] This quantity, 87 μg/m³, differs from the standard error of the mean of individual measurements for underground M/NM mines, presented in Table III–1. The tabled value is based on 355 measurements whose standard deviation is 727 μg/m³. Therefore, the standard error of the mean of all individual measurements is $_{727}/\sqrt{_{355}}$ = 39 μg/m³, as shown in the table. Similarly, the mean of all individual measurements (listed in Table III–1 as 808 μg/m³) differs from the grand mean of individual mean concentrations observed within mines, which is 838 μg/m³.

MSHA considers the size-selective, gravimetric method capable of providing reasonably accurate measurements when the dpm concentration is greater than 200 µg/m^3, interferences are adequately limited, and the measurement is based on a full-shift sample. Relatively few M/NM measurements were made using this method, and none at the mines showing the highest dpm concentrations. No evidence was presented that the size distribution of coal mine dust (for which the impactor was specifically developed) differs from that of other mineral dusts in a way that significantly alters the impactor's performance. Similarly, MSHA considers the RCD method, when properly applied, to be capable of providing reasonably accurate dpm measurements at concentrations greater than 200 µg/m^3. As with the size selective method, however, random weighing errors can significantly reduce the precision of even full-shift RCD measurements at lower dpm concentrations. For this reason, in order to maintain a sufficiently high confidence level for its noncompliance determinations, MSHA will not use the RCD method for enforcement purposes. This does not mean, however, that MSHA has ''discredited'' the RCD measurements for all other purposes, including detection of very high dpm concentrations (i.e., greater than 300 µg/m^3) and estimation of average concentrations based on multiple samples. On the contrary, MSHA considers the RCD method to be a useful tool for detecting and monitoring very high dpm concentrations in appropriate environments and for estimating average exposures when those exposures are excessive.

MSHA did not employ an impactor in its RCD measurements, and it is true that some of these measurements may have been subject to interference from lubrication oil mists. However, MSHA believes that the high estimates sometimes made of the non-dpm component of RCD (cited by IMC Global) do not apply to the RCD measurements depicted in Figure III–2. MSHA has three reasons for believing these RCD measurements consisted almost entirely of dpm:

(1) MSHA took special care to sample only environments where interferences would not be significant. No samples were taken near pneumatic drills or smoking miners.

(2) There was no interference from carbonates. The RCD analysis was performed at 500° C, and carbonates are not released below 1000° C. (Gangel and Dainty, 1993)

(3) Although high sulphur fuel was used in some mines, thereby adding sulfates to the RCD measurement, these sulfates are considered part of the dpm, as explained in section 2 of Part II of this preamble. Sulfates should not be regarded as an interference in RCD measurements of dpm.

Commenters presented no evidence that there were substantial interferences in MSHA's RCD measurements, and, as stated above, MSHA was careful to avoid them. Therefore, MSHA considers it reasonable, in the context of this risk assessment, to assume that all of the RCD was in fact dpm. Moreover, in the majority of underground M/NM mines sampled, even if the RCD measurements were reduced by ⅓, the mine's average would still be excessive: it would still exceed the maximum exposure level reported for non-mining occupations presented in Section III.1.d.

The breakdown, as suggested by IMC Global, of sampled underground M/NM mines by commodity is as follows:

Commodity	Number of mines
Copper	2
Gold	1
Lead/Zinc	6
Limestone	6
Potash	2
Salt	6
Trona (soda ash)	2
Other Nonmetal	2
Total	27

c. Surface Mines

Currently, there are approximately 12,620 surface mining operations in the United States. The total consists of approximately 1,550 coal mines and 11,070 M/NM mines. Virtually all of these mines utilize diesel powered equipment.

MSHA conducted dpm studies at eleven surface mining operations: eight coal mines and three M/NM mines. MSHA deliberately directed its surface sampling efforts toward occupations likely to experience high dpm concentrations. To help select such occupations, MSHA first made a visual examination (based on blackness of the filter) of surface mine respirable dust samples collected during a November 1994 study of surface coal mines. This preliminary screening of samples indicated that relatively high surface mine dpm concentrations are typically associated with front-end-loader operators and haulage-truck operators; accordingly, sampling focused on these operations. A total of 45 samples was collected.

Figure III–3 displays the range of dpm concentrations measured at the eleven surface mines. The average dpm concentration observed was less than 200 µg/m^3 at all mines sampled. The maximum dpm concentration observed was less than or equal to 200 µg/m^3 in 8 of the 11 mines (73%). The surface mine studies suggest that even when sampling is performed at the areas of surface mines believed most likely to have high exposures, dpm concentrations are generally likely to be less than 200 µg/m^3.

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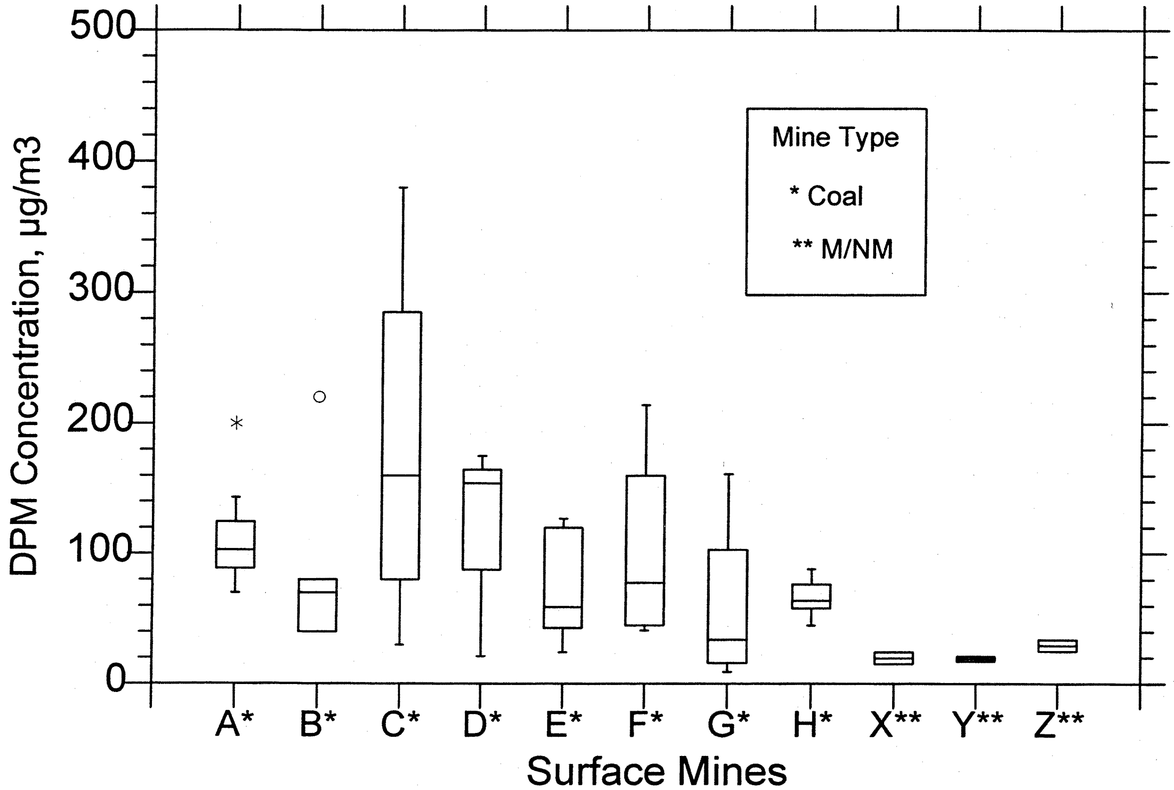

Figure 7Box plots (Tukey, 1977) for dpm concentrations observed at 11 surface mines. Top and bottom of each box represent upper and lower quartiles, respectively. "Belt" inside box represents median. Vertical lines span nearly all measurements. Isolated points (either ✳ or ○) are outliers, representing unusually high or low measurements compared to other observations at the same mine. All dpm measurements were made using the size-selective method, based on gravimetric determination of the amount of submicrometer dust collected with an impactor. Because of potential interferences from cigarette smoke, samples were not collected on smokeres who worked inside enclosures.

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d. Miner Exposures Compared to Exposures of Other Groups

Occupational exposure to diesel particulate primarily originates from industrial operations employing equipment powered with diesel engines. Diesel engines are used to power ships, locomotives, heavy duty trucks, heavy machinery, as well as a small number of light-duty passenger cars and trucks. NIOSH has estimated that approximately 1.35 million workers are occupationally exposed to the combustion products of diesel fuel in approximately 80,000 workplaces in the United States. (NIOSH 1988) Workers who are likely to be exposed to diesel emissions include: mine workers; bridge and tunnel workers; railroad workers; loading dock workers; truck drivers; fork-lift drivers; farm workers; and, auto, truck, and bus maintenance garage workers (NIOSH, 1988). Besides miners, groups for which occupational exposures have been reported and health effects have been studied include loading dock workers, truck drivers, and railroad workers.

As estimated by the reported geometric mean,[15] the median site-specific occupational exposures for loading dock workers operating or otherwise exposed to unfiltered diesel fork lift trucks ranged from 23 to 55 μg/m^3, as measured by submicrometer elemental carbon (EC) (NIOSH, 1990). Reported geometric mean concentrations of submicrometer EC ranged from 2.0 to 7.0 μg/m^3 for truck drivers and from 4.8 to 28 μg/m^3 for truck mechanics, depending on weather conditions (Zaebst et al., 1991).

Because these exposure averages, unlike those for railroad workers and miners, were reported in terms of EC, it is necessary, for purposes of comparison, to convert them to estimates of total dpm. Watts (1995) states that ''elemental carbon generally accounts for about 40% to 60% of diesel particulate mass.'' Therefore, in earlier versions of this risk assessment, a 2.0 conversion factor was assumed for dock workers, truck drivers, and truck mechanics, based on the midpoint of the 40–60% range proposed by Watts.

Some commenters objected to MSHA's use of this conversion factor. IMC Global, for example, asserted that Watts' ''* * * 40 to 60% relationship between elemental carbon and diesel particulate mass * * * applies only to underground coal mines where diesel haulage equipment is used.'' IMC Global, and other commenters, also objected to MSHA's use of a single conversion factor for ''* * * different types of diesel engines under different duty cycles with different fuels and different types of emission control devices (if any) subjected to varying degrees of maintenance.''

MSHA's quotation from Watts (1995) was taken from the ''Summary'' section of his paper. That paper covers a variety of occupational environments, and the summary makes no mention of coal mines. The sentence immediately preceding the quoted passage refers to the ''occupational environment'' in general, and there is no indication that Watts meant to restrict the 40- to 60-percent range to any specific environment. It seems clear that the 40- to 60-percent range refers to average values across a spectrum of occupational environments.

IMC Global mistakenly attributed to MSHA ''the blanket statement'' that the same ratio of elemental carbon to dpm applies ''for all diesel engines in different industries for all patterns of use.'' MSHA made no such statement. On the contrary, MSHA agrees with Watts (and IMC Global) that ''the percentage of elemental carbon in total diesel particulate matter fluctuates'' depending on ''engine type, duty cycle, fuel, lube oil consumption, state of engine maintenance, and the presence or absence of an emission control device.'' (Watts, op cit.) Indeed, MSHA acknowledges that, because of these factors, the percentage on a particular day in a particular environment may frequently fall outside the stated range. But MSHA is not applying a single conversion factor to individual elemental carbon measurements and claiming knowledge of the total dpm corresponding to each separate measurement. Instead, MSHA is applying an average conversion factor to an average of measurements in order to derive an estimate of an average dpm exposure. Averages are always less widely dispersed than individual values.

[15] Median concentrations were not reported. The geometric mean provides a smoothed estimate of the median.

Still, MSHA agrees with IMC Global that better estimates of dpm exposure levels are attainable by applying conversion factors more specifically related to the separate categories within the trucking industry: dock workers, truck drivers, and truck mechanics. Based on a total of 63 field measurements, the mean ratios (in percent) of EC to total carbon (TC) reported for these three categories were 47.3, 36.6, and 34.2, respectively (Zaebst et al., 1991).[16] As explained elsewhere in this preamble, TC amounts to approximately 80 percent, by weight, of total dpm. Therefore, each of these ratios must be multiplied by 0.8 in order to estimate the corresponding percentage of EC in dpm.

It follows that the median mass concentration of dpm can be estimated as 2.64 (i.e., $1/(0.473 \times 0.8)$) times the geometric mean EC reported for dock workers, 3.42 times the geometric mean EC for truck drivers, and 3.65 times the geometric mean EC for truck mechanics. Applying the 2.64 conversion factor to the range of geometric mean EC concentrations reported for dock workers (i.e., 23 to 55 $\mu g/m^3$) results in an estimated range of 61 to 145 $\mu g/m^3$ in median dpm concentrations at various docks. Similarly, the estimated range of median dpm concentrations is calculated to be 6.8 to 24 $\mu g/m^3$ for truck drivers and 18 to 102 $\mu g/m^3$ for truck mechanics. It should be noted that MSHA is using conversion factors only for those occupational groups whose geometric mean exposures have been reported in terms of EC measurements.

Average exposures of railroad workers to dpm were estimated by Woskie et al. (1988) and Schenker et al. (1990). As measured by total respirable particulate matter other than cigarette smoke, Woskie et al. reported geometric mean concentrations for various occupational categories of exposed railroad workers ranging from 49 to 191 $\mu g/m^3$.

For comparison with the exposures reported for these other industries, median dpm exposures measured within sampled mines were calculated directly from the data described in subsections a, b, and c above. The median within each mine is shown as the horizontal ''belt'' plotted for the mine in Figures III–1, III–2, and III–3.

Figure III–4 compares the range of median dpm concentrations observed for mine workers within different mines to a range of dpm exposure levels estimated for urban ambient air and to the ranges of median dpm concentrations estimated for loading dock workers operating or otherwise exposed to diesel fork lift trucks, truck drivers, truck mechanics, and railroad workers. The range for ambient air, 1 to 10 $\mu g/m^3$, was obtained from Cass and Gray (1995). For dock workers, truck drivers, truck mechanics, and railroad workers, the estimated ranges of median dpm exposures are, respectively: 61 to 145 $\mu g/m^3$, 6.8 to 24 $\mu g/m^3$, 18 to 102 $\mu g/m^3$ and 49 to 191 $\mu g/m^3$. The range of median dpm concentrations observed at different underground coal mines is 55 to 2100 $\mu g/m^3$, with filters employed at mines showing the lower concentrations.[17] For underground M/NM mines, the corresponding range is 68 to 1835 $\mu g/m^3$, and for surface mines it is 19 to 160 $\mu g/m^3$. Since each range plotted is a range of median values or (for ambient air) mean values, the plots do not encompass all of the individual measurements reported.

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[16] MSHA calculated the ratio for truck drivers by taking a weighted average of the ratios reported for ''local drivers'' and ''road drivers.''

[17] One commenter misinterpreted the tops of the ranges plotted in Figure III–4. This commenter apparently mistook the top of the range depicted for underground coal mines as the mean or median dpm exposure concentration measured across all underground coal mines. The top of this range (at 2100 $\mu g/m^3$, actually represents the highest median concentration at any of the coal mines sampled. It corresponds to the ''belt'' plotted for Mine ''G'' (with no after-filters) in Figure III–1. The bottom of the same bar, at 55 $\mu g/m^3$, corresponds to the ''belt'' plotted for Mine H * (with after-filters) in Figure III–1.

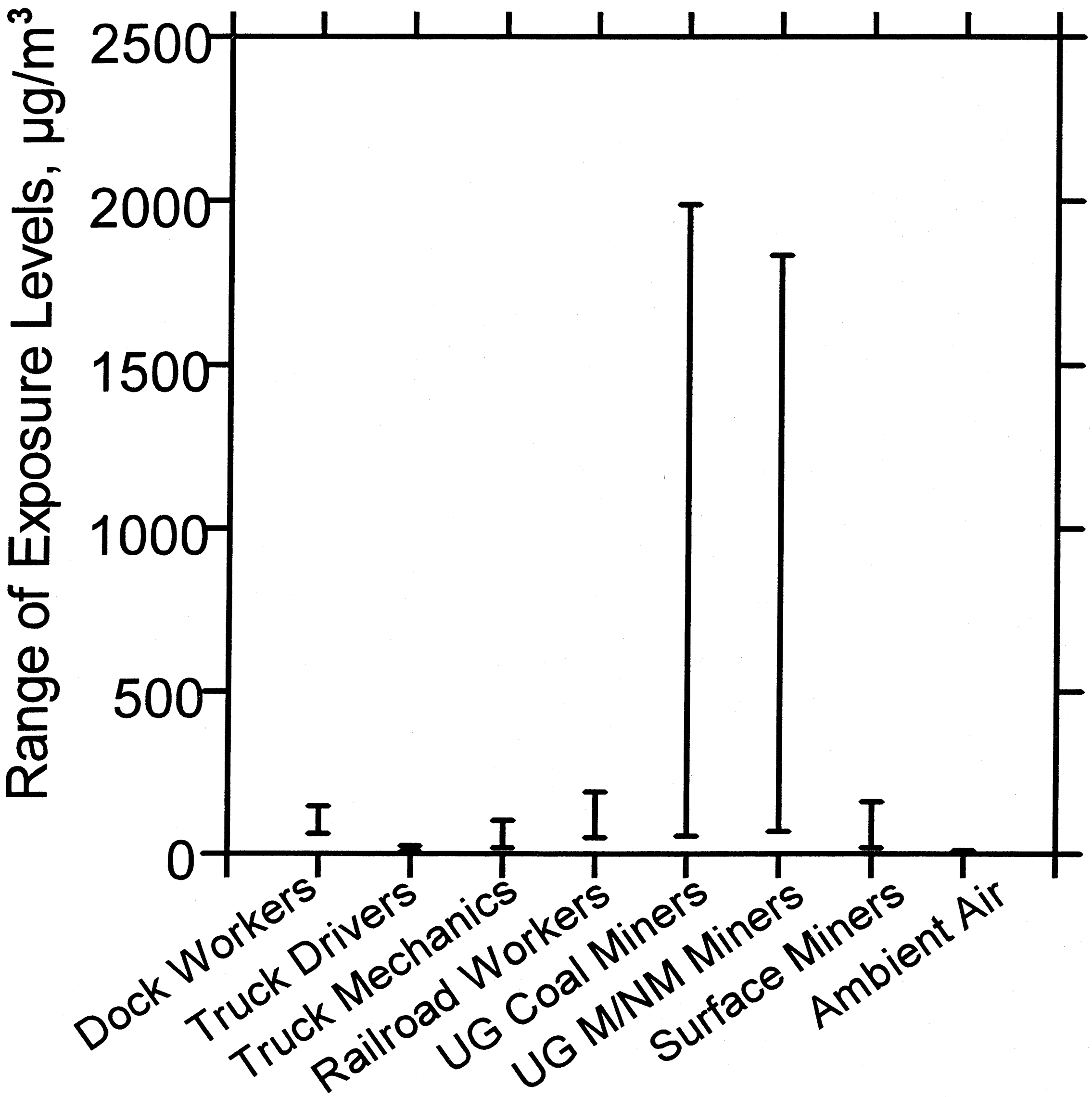

Figure III-4. — Range of median dpm exposure levels observed within various mines for underground and surface miners compared to range of median dpm exposure levels estimated for other occupations. Range of dpm exposure levels for ambient air is for urban environments only and is based on the monthly mean for different months and locations in Southern California. Range for ambient air is roughly 1 to 10 $\mu g/m^3$.

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As shown in Figure III–4, some miners are exposed to far higher concentrations of dpm than are any other populations for which exposure data have been reported. Indeed, median dpm concentrations observed in some underground mines are up to 200 times as high as mean environmental exposures in the most heavily polluted urban areas,[18] and up to 10 times as high as median exposures estimated for the most heavily exposed workers in other occupational groups.

Several commenters objected to Figure III–4 and, more generally, to MSHA's comparison of dpm exposure levels for miners against the levels reported for other occupations. The objections to MSHA's method of estimating ranges of median dpm exposure for job categories within the trucking industry have already been discussed and addressed above. Other objections to the comparison were based on claims of insufficient accuracy in the RCD and gravimetric size selective measurements MSHA used to measure dpm levels for miners. MSHA considers its use of these methods appropriate for purposes of this comparison and has responded to criticisms of the dpm measurements for miners in Subsections 1.a and 1.b of this risk assessment.[19]

Some commenters objected to MSHA's basing a characterization of dpm exposures to miners on data spanning a ten-year period. These commenters contended that, in at least some M/NM mines, dpm levels had improved substantially during that period. No data were submitted, however, to support the premise that dpm exposures throughout the mining industry have declined to the levels reported for other occupations. As stated in the proposal and emphasized above, MSHA's dpm measurements were not technically designed as a random or statistically representative sample of the industry. They do show, however, that very high exposures have recently occurred in some mines. For example, as shown in Figure III–2, more than 25 percent of MSHA's dpm measurements exceeded 2000 $\mu g/m^3$ at underground M/NM mines ''U'' and ''Z''—and these measurements were made in 1996–7. In M/NM mines where exposures are actually commensurate with other industries already, little or nothing would need to be changed to meet the exposure limits.

IMC Global further objected to Figure III–4 on the grounds that ''* * * the assumptions that MSHA used to develop that figure are grossly inaccurate and do not make sense in the context of a dose-response relationship between lung cancer and Dpm exposure.'' IMC Global suggested that the comparison in Figure III–4 be deleted for this reason. MSHA believes that the comparison is informative and that empirical evidence should be used, when it is available, even though the evidence was not generated under ideal, theoretical dose-response model conditions. The issue of whether Figure III–4 is consistent with an exposure-response relationship for dpm is addressed in Subsection 3.a.iii(4) of this risk assessment.

2. Health Effects Associated With Dpm Exposures

This section reviews the various health effects (of which MSHA is aware) that may be associated with dpm exposures. The review is divided into three main sections: acute effects, such as diminished pulmonary function and eye irritation; chronic effects, such as lung cancer; and mechanisms of toxicity. Prior to that review, however, the relevance of certain types of information will be considered. This discussion will address the relevance of health effects observed in animals, health effects that are reversible, and health effects associated with fine particulate matter in the ambient air.

Several commenters described medical surveillance studies that NIOSH and/or the former Bureau of Mines had carried out in the late 1970s and early 1980s on underground miners employed in western, dieselized coal mines. These commenters urged MSHA to make these studies available and to consider the results in this rulemaking. Some of these commenters also suggested that these data would provide a useful baseline for pulmonary function and lung diseases among miners exposed to dpm, and recommended that follow-up examinations now be conducted to evaluate the possible effects of chronic dpm exposure.

In response to such comments presented at some of the public hearings, another commenter wrote:

> First of all, MSHA is not a research agency, it is a regulatory agency, so that it would be inappropriate for MSHA to initiate research. MSHA did request that NIOSH conduct a risk assessment on the health effects of diesel exhaust and encouraged NIOSH and is currently collaborating with NIOSH (and NCI) on research of other underground miners exposed to diesel exhaust. And third, research on the possible carcinogenicity of diesel particulate matter was not undertaken on coal miners in the West or anywhere else because of the confounding exposure to crystalline silica, also considered a carcinogen, because too few coal miners have been exposed, and for too short a time to conduct a valid study. It was not arbitrariness or indifference on MSHA's part that it did not initiate research on coal miners; it was not within their mandate and it is inappropriate in any event. [UMWA]

Three reports summarizing and presenting results from these medical surveillance studies related to dpm exposures in coal mines were, in fact, utilized and cited in the proposed risk assessment (Ames *et al.,* 1982; Reger *et al.,* 1982; Ames *et al.,* 1984). Ames *et al.* (1982) evaluated acute respiratory effects, and their results are considered in Subsection 2.b.ii of this risk assessment. Reger *et al.* (1982) and Ames *et al.* (1984) evaluated chronic effects, and their results are considered in Subsection 2.c.i(1).

A fourth report (Glenn *et al.*, 1983) summarized results from the overall research program of which the coal mine studies were a part. This health and environmental research program included not only coal miners, but also workers at potash, trona, salt, and metal mines. All subjects were given chest radiographs and spirometric tests and were questioned about respiratory symptoms, smoking and occupational history. In conjunction with these medical evaluations, industrial hygiene surveys were conducted to characterize the mine environments where diesel equipment was used. Diesel exhaust exposure levels were characterized by area and personal samples of NO2 (and, in some cases, additional gasses), aldehydes, and both respirable and total dust. For the evaluations of acute effects, exposure measures were based on the shift concentrations to which the examined workers were exposed. For the evaluations of chronic effects, exposures were usually estimated by summing the products of time spent in various locations by each miner by concentrations estimated for the various locations. Results of studies on acute effects in salt mines were reported by Gamble *et al.* (1978) and are considered

[18] It should be noted, however, that 24-hour environmental exposures for a full lifetime are not directly comparable with workday exposures over an occupational lifetime. If it is assumed that air inhaled during a work shift comprises half the total air inhaled during a 24-hour day, then the amount of air inhaled over the course of a 70-year lifetime is approximately 4.7 times the amount inhaled over a 45-year occupational lifetime with 240 working days per year.

[19] One commenter pointed out that the measurements for miners included both area and personal samples but provided no evidence that this would invalidate the comparison. As pointed out in Subsections 1.a and 1.b, area samples did not dominate the upper end of MSHA's dpm measurements. Furthermore, Figure III–4 presents a comparison of medians rather than means or individual measurements, so inclusion of the area samples has very little impact on the results.

in Subsection 2.b.ii of this risk assessment. Attfield (1979), Attfield *et al.* (1982), and Gamble *et al.* (1983) evaluated effects in M/NM mines, and their results are considered in Subsection 2.c.i(1). The general summary provided by Glenn *et al.* (1983) was among the reports that one commenter (MARG) listed as having received inadequate attention in the proposed risk assessment. In that context, the general results summarized in this report are discussed, under the heading of ''Counter-Evidence,'' in Subsection 2.c.i(2)(a) of this risk assessment.

a. Relevancy Considerations

i. Animal Studies

Since the lungs of different species may react differently to particle inhalation, it is necessary to treat the results of animal studies with some caution. Evidence from animal studies can nevertheless be valuable—both in helping to identify potential human health hazards and in providing a means for studying toxicological mechanisms. Respondents to MSHA's ANPRM who addressed the question of relevancy urged consideration of all animal studies related to the health effects of diesel exhaust.

Unlike humans, laboratory animals are bred to be homogeneous and can be randomly selected for either non-exposure or exposure to varying levels of a potentially toxic agent. This permits setting up experimental and control groups of animals that exhibit relatively little biological variation prior to exposure. The consequences of exposure can then be determined by comparing responses in the experimental and control groups. After a prescribed duration of deliberate exposure, laboratory animals can also be sacrificed, dissected, and examined. This can contribute to an understanding of mechanisms by which inhaled particles may exert their effects on health. For this reason, discussion of the animal evidence is placed in the section entitled ''Mechanisms of Toxicity'' below.

Animal evidence also can help isolate the cause of adverse health effects observed among humans exposed to a variety of potentially hazardous substances. If, for example, the epidemiologic data are unable to distinguish between several possible causes of increased risk of disease in a certain population, then controlled animal studies may provide evidence useful in suggesting the most likely explanation—and provide that information years in advance of definitive evidence from human observations.

Furthermore, results from animal studies may also serve as a check on the credibility of observations from epidemiologic studies of human populations. If a particular health effect is observed in animals under controlled laboratory conditions, this tends to corroborate observations of similar effects in humans.

One commenter objected to MSHA's reference to using animal studies as a ''check'' on epidemiologic studies. This commenter emphasized that animal studies provide far more than just corroborative information and that researches use epidemiologic and animal studies ''* * * to help understand different aspects of the carcinogenic process.'' [20] MSHA does not dispute the utility of animal studies in helping to provide an understanding of toxicological processes and did not intend to belittle their importance for this purpose. In fact, MSHA places the bulk of its discussion of these studies in a section entitled ''Mechanisms of Toxicity.'' However, MSHA considers the use of animal studies for corroborating epidemiologic associations to be also important—especially with respect to ruling out potential confounding effects and helping to establish causal linkages. Animal studies make possible a degree of experimental design and statistical rigor that is not attainable in human studies.

Other commenters disputed the relevance of at least some animal data to human risk assessment. For example, The West Virginia Coal Association indicated the following comments by Dr. Peter Valberg:

> * * * scientists and scientific advisory groups have treated the rat bioassay for inhaled particles as unrepresentative of human lung-cancer risks. For example, the Presidential/Congressional Commission on Risk Assessment and Risk Management (''CCRARM'') noted that the response of rat lungs to inhaled particulate in general is not likely to be predictive of human cancer risks. More specific to dpm, the Clean Air Scientific Advisory Committee (''CASAC''), a peer-review group for the U.S. EPA, has commented on two drafts (1995 and 1998) of the EPA's Health Assessment Document on Diesel Exhaust. On both occasions, CASAC emphasized that the data from rats are not relevant for human risk assessment. Likewise, the Health Effects Institute also has concluded that rat data should not be used for assessing human lung cancer risk.

Similarly, the NMA commented that the 1998 CASAC review ''makes it crystal clear that the rat studies cited by MSHA should not be relied upon as a legitimate indicators of the carcinogenicity of Dpm in humans.'' The Nevada Mining Association, endorsing Dr. Valberg's comments, added:

> * * * to the extent that MSHA wishes to rest its case on rat studies, Dr. Valberg, among others, has impressively demonstrated that these studies are worthless for human comparison because of rats' unique and species-specific susceptibility to inhaled insoluble particles.

However, neither Dr. Valberg nor the Nevada Mining Association provided evidence that rats' susceptibility to inhaled insoluble particles was ''unique'' and that humans, for example, were not also susceptible to lung overload at sufficiently high concentrations of fine particles. Even if (as has apparently been demonstrated) some species (such as hamsters) do not exhibit susceptibility similar to rats, this by no means implies that rats are the only species exhibiting such susceptibility.

These commenters appear at times to be saying that, because studies of lung cancer in rats are (in the commenters' view) irrelevant to humans, MSHA should completely ignore all animal studies related to dpm. To the extent that this was the position advocated, the commenters' line of reasoning neglects several important points:

1. The animal studies under consideration are not restricted to studies of lung cancer responses in rats. They include studies of bioavailability and metabolism as well as studies of immunological and genotoxic responses in a variety of animal species.

2. The context for the determinations cited by Dr. Valberg was risk assessment at ambient levels, rather than the much higher dpm levels to which miners are exposed. The 1995 HEI report to which Dr. Valberg alludes acknowledged a potential mechanism of lung overload in humans at dpm concentrations exceeding 500 $\mu g/m^3$ (HEI, 1995). Since miners may concurrently be exposed to concentrations of mineral dusts significantly exceeding 500 $\mu g/m^3$, evidence related to the consequences of lung overload has special significance for mining environments.

3. The scientific authorities cited by Dr. Valberg and other commenters objected to using existing animal studies for quantitative human risk assessment. MSHA has not proposed doing that. There is an important distinction between extrapolating results from the rat studies to human populations and using them to confirm epidemiologic

[20] This risk assessment is not limited to cancer effects, but the commenter's point can be generalized.

findings and to identify and explore potential mechanisms of toxicity.

MSHA by no means ''wishes to rest its case on rat studies,'' and it has no intention of doing so. MSHA does believe, however, that judicious consideration of evidence from animal studies is appropriate. The extent to which MSHA utilizes such evidence to help draw specific conclusions will be clarified below in connection with those conclusions.

ii. Reversible Health Effects

Some reported health effects associated with dpm are apparently reversible—*i.e.*, if the worker is moved away from the source for a few days, the symptoms dissipate. A good example is eye irritation.

In response to the ANPRM, questions were raised as to whether so-called ''reversible'' effects can constitute a ''material'' impairment. For example, a predecessor constituent of the National Mining Association (NMA) argued that ''it is totally inappropriate for the agency to set permissible exposure limits based on temporary, reversible sensory irritation'' because such effects cannot be a ''material'' impairment of health or functional capacity within the definition of the Mine Act (American Mining Congress, 87–0–21, Executive Summary, p. 1, and Appendix A).

MSHA does not agree with this categorical view. Although the legislative history of the Mine Act is silent concerning the meaning of the term ''material impairment of health or functional capacity,'' and the issue has not been litigated within the context of the Mine Act, the statutory language about risk in the Mine Act is similar to that under the OSH Act. A similar argument was dispositively resolved in favor of the Occupational Safety and Health Administration (OSHA) by the 11th Circuit Court of Appeals in *AFL–CIO* v. *OSHA,* 965 F.2d 962, 974 (1992).

In that case, OSHA proposed new limits on 428 diverse substances. It grouped these into 18 categories based upon the primary health effects of those substances: *e.g.,* neuropathic effects, sensory irritation, and cancer. (54 FR 2402). Challenges to this rule included the assertion that a ''sensory irritation'' was not a ''material impairment of health or functional capacity'' which could be regulated under the OSH Act. Industry petitioners argued that since irritant effects are transient in nature, they did not constitute a ''material impairment.'' The Court of Appeals decisively rejected this argument.

The court noted OSHA's position that effects such as stinging, itching and burning of the eyes, tearing, wheezing, and other types of sensory irritation can cause severe discomfort and be seriously disabling in some cases. Moreover, there was evidence that workers exposed to these sensory irritants could be distracted as a result of their symptoms, thereby endangering other workers and increasing the risk of accidents. (*Id.* at 974). This evidence included information from NIOSH about the general consequences of sensory irritants on job performance, as well as testimony by commenters on the proposed rule supporting the view that such health effects should be regarded as material health impairments. While acknowledging that ''irritation'' covers a spectrum of effects, some of which can be minor, OSHA had concluded that the health effects associated with exposure to these substances warranted action—to ensure timely medical treatment, reduce the risks from increased absorption, and avoid a decreased resistance to infection (*Id.* at 975). Finding OSHA's evaluation adequate, the Court of Appeals rejected petitioners' argument and stated the following:

> We interpret this explanation as indicating that OSHA finds that although minor irritation may not be a material impairment, there is a level at which such irritation becomes so severe that employee health and job performance are seriously threatened, even though those effects may be transitory. We find this explanation adequate. OSHA is not required to state with scientific certainty or precision the exact point at which each type of sensory or physical irritation becomes a material impairment. Moreover, section 6(b)(5) of the Act charges OSHA with addressing all forms of ''material impairment of health or functional capacity,'' and not exclusively ''death or serious physical harm'' or ''grave danger'' from exposure to toxic substances. See 29 U.S.C. 654(a)(1), 655(c). [*Id.* at 974].

In its comments on the proposed rule, the NMA claimed that MSHA had overstated the court's holding. In making this claim, the NMA attributed to MSHA an interpretation of the holding that MSHA did not put forth. In fact, MSHA agrees with the NMA's interpretation as stated in the following paragraph and takes special note of the NMA's acknowledgment that transitory or reversible effects can sometimes be so severe as to seriously threaten miners' health and safety:

> NMA reads the Court's decision to mean (as it stated) that ''minor irritation may not be a material impairment'' * * * but that irritation can reach ''a level at which [it] becomes so severe that employee health and job performance are seriously threatened even though those effects may be transitory.'' * * * AMC in 1992 and NMA today are fully in accord with the view of the 11th Circuit that when health effects, transitory or otherwise, become so ''severe'' as to ''seriously threaten'' a miner's health or job performance, the materiality threshold has been met.

The NMA, then, apparently agrees with MSHA that sensory irritations and respiratory symptoms can be so severe that they cross the material impairment threshold, regardless of whether they are ''reversible.'' Therefore, as MSHA has maintained, such health effects are highly relevant to this risk assessment—especially since impairments of a miner's job performance in an underground mining environment could seriously threaten the safety of both the miner and his or her co-workers. Sensory irritations may also impede miners' ability to escape during emergencies.

The NMA, however, went on to emphasize that ''* * * federal appeals courts have held that 'mild discomfort' or even 'moderate irritation' do not constitute 'significant' or 'material' health effects'':

> In International Union v. Pendergrass, 878 F. 2d 389 (1989), the D.C. Circuit upheld OSHA's formaldehyde standard against a challenge that it did not adequately protect against significant noncarcinogenic health effects, even though OSHA had found that, at the permissible level of exposure, ''20% of workers suffer 'mild discomfort', while 30% more experience 'slight discomfort'.'' Id. at 398. Likewise, in *Texas Independent Ginners Ass'n.* v. *Marshall,* 630 F, 2d 398 (1980), the Fifth Circuit Court of Appeals held that minor reversible symptoms do not constitute material impairment unless OSHA shows that those effects might develop into chronic disease. Id. at 408–09.

MSHA is fully aware of the distinction that courts have made between mild discomfort or irritation and transitory health effects that can seriously threaten a miner's health and safety. MSHA's position, after reviewing the scientific literature, public testimony, and comments, is that all of the health effects considered in this risk assessment fall into the latter category.

iii. Health Effects Associated with $PM_{2.5}$ in Ambient Air

There have been many studies in recent years designed to determine whether the mix of particulate matter in ambient air is harmful to health. The evidence linking particulates in air pollution to health problems has long been compelling enough to warrant direction from the Congress to limit the concentration of such particulates (see part II, section 5 of this preamble). In recent years, the evidence of harmful effects due to airborne particulates has increased, suggesting that ''fine'' particulates (i.e., particles less than 2.5